Radiological Health Data

VOLUME 6, NUMBER 1

JANUARY 1965

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FEB - 9 1965
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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service

In August 1959, the President directed the Secretary of Health, Education, and Welfare to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis and interpretation of data on environmental radiation levels. The Department delegated this responsibility to the Division of Radiological Health, Public Health Service.

Radiological Health Data is published by the Public Health Service on a monthly basis. Data are provided to the Division of Radiological Health by other Federal agencies, State health departments, and foreign governments. Pertinent original data and interpretive papers are invited from investigators. Accepted material will be appropriately credited. The reports are reviewed by a Board of Editorial Advisors with representatives from the following Federal agencies:

Department of Health, Education, and Welfare
Atomic Energy Commission
Department of Defense
Department of Agriculture
Department of Commerce

Contributions may be sent to the Radiation Surveillance Center, Division of Radiological Health, Public Health Service, Washington, D.C. 20201.

For further information on any subject reported in this issue, readers are referred to the contributors indicated in article headings.

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Section I—Air and Fallout

FISSION PRODUCT BETA ACTIVITY IN AIRBORNE PARTICULATES AND PRECIPITATION

Continuous surveillance of gross beta activity in air and precipitation provides one of the earliest and most sensitive indications of changes in environmental fission product activity. Although this surveillance does not provide enough information to assess human radiation exposure from fallout, it is widely used as the basis for alerting systems to determine when to intensify monitoring in other phases of the environment.

Surveillance data from a number of national programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. Data provided by programs of the Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization are presented individually in tabular form and are also compared in beta concentration isograms.

1. Radiation Surveillance Network September 1964

Division of Radiological Health, Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Surveillance Network (RSN) of the PHS Division of Radiological Health which gathers samples from 74 stations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The alerting function of the network is provided by field estimates of the gross beta activity of airborne particulates on the filters. These determinations are performed about 5 hours after the end of the sampling period to allow for decay of naturally-occurring radon daughters. The network station operators regularly submit their field estimates to the Radiation Surveillance Center, Division of Radiological Health, Washington, D. C. These field estimates are reported elsewhere on a monthly basis (*1*). When unusually high air levels are reported, appropriate Federal and State officials are promptly notified.

Air

Airborne particulates are collected continuously on a carbon-loaded cellulose dust filter 4 inches in diameter. A volume of about 1,800 cubic meters of air is drawn through each filter during the 24-hour sampling period by a high volume centrifugal blower.

The filters are forwarded to the Radiation Surveillance Network laboratory in Rockville, Maryland, where the gross beta activity is measured using a thin-window, gas-flow proportional counter, calibrated with a Sr^{90}–Y^{90} standard. Each filter is counted at least 3 days after the end of the sampling period and again 7 days later. The initial 3-day aging of the sample eliminates interference from naturally-occurring radon and thoron daughters. By using the two counts and the Way-Wigner formula (*2*), the age of fission products is estimated, and the activity extrapolated to the

TABLE 1.—GROSS BETA ACTIVITY IN SURFACE AIR AND PRECIPITATION, SEPTEMBER 1964

Station location		Air surveillance				Precipitation measurements		
		Number of samples	Gross beta activity (pc/m³)			Last profile in *RHD*	Average concentration (pc/liter)	Total deposition (nc/m²)
			Maximum	Minimum	Average [a]			
Ala:	Montgomery	21	1.10	<0.10	0.54	Aug 64	200	16.0
Alaska:	Adak	23	0.78	<0.10	0.16	Nov 64	[b]	
	Anchorage	30	0.53	<0.10	0.18	Jul 64	200	3.5
	Attu Island	29	0.44	<0.10	0.16	Dec 64		
	Fairbanks	23	0.37	<0.10	0.16	Aug 64	300	6.7
	Juneau	02	0.13	<0.10	0.10	Sep 64	200	5.5
	Kodiak	24	0.81	<0.10	0.21	Oct 64		
	Nome	13	0.38	<0.10	0.14	Feb 64		
	Point Barrow					Jan 65		
	St. Paul Island	24	0.59	<0.10	0.17	Mar 64		
Ariz:	Phoenix	27	1.16	<0.10	0.42	Sep 64		
Ark:	Little Rock	24	1.16	<0.10	0.38	Sep 64	200	24.3
Calif:	Berkeley	19	0.48	<0.10	0.27	Oct 64		
	Los Angeles	20	0.71	0.22	0.36	Jan 65		
Canal Zone:	Ancon	17	0.10	<0.10	0.10	Nov 64		
Colo:	Denver	26	1.06	0.11	0.41	Oct 64	200	2.8
Conn:	Hartford	27	0.79	<0.10	0.42	Oct 64	210	9.4
Del:	Dover	20	0.94	<0.10	0.57	Aug 64		
D. C:	Washington	29	1.11	<0.10	0.56	Aug 64	230	23.3
Fla:	Jacksonville	26	1.19	0.11	0.54	Sep 64	200	7.9
	Miami	30	1.00	<0.10	0.34	Oct 64	210	10.2
Ga:	Atlanta	13	0.50	0.13	0.32	Jul 64		
Guam:	Agana	30	0.22	<0.10	0.11	Apr 64		
Hawaii:	Honolulu	27	0.43	<0.10	0.20	Dec 64	200	4.1
Idaho:	Boise	28	1.11	0.13	0.45	Dec 64		
Ill:	Springfield	27	1.13	0.14	0.48	Mar 64	220	4.1
Ind:	Indianapolis	29	1.25	<0.10	0.54	Jul 64	240	16.6
Iowa:	Iowa City	28	0.73	<0.10	0.31	Nov 64	200	8.8
Kans:	Topeka	22	0.70	<0.10	0.27	Jul 64	200	13.1
Ky:	Frankfort	30	1.22	<0.10	0.64	Jan 65	400	14.1
La:	New Orleans	27	0.76	<0.10	0.29	Mar 64	210	23.3
Maine:	Augusta	30	0.97	<0.10	0.37	Mar 64	240	12.5
	Presque Isle	25	0.56	<0.10	0.26	Nov 64	280	6.8
Md:	Baltimore	21	1.01	0.13	0.48	Oct 64	250	8.7
	Rockville	08	0.70	<0.10	0.31	Mar 64		
Mass:	Lawrence	29	1.04	<0.10	0.46	Aug 64	240	8.5
	Winchester	26	1.06	<0.10	0.48	Dec 64	300	15.7
Mich:	Lansing	30	1.36	<0.10	0.63	Jan 65	290	14.4
Minn:	Minneapolis	30	0.38	<0.10	0.18	Mar 64	200	23.9
Miss:	Jackson	30	1.07	<0.10	0.56	Apr 64	200	11.7
	Pascagoula	12	1.22	<0.10	0.48	Dec 64		
Mo:	Jefferson City	30	0.83	<0.10	0.30	Jul 64	200	23.0
Mont:	Helena	29	1.33	0.12	0.47	Nov 64	570	3.7
Nebr:	Lincoln	18	1.07	<0.10	0.60	Apr 63		
Nev:	Las Vegas	25	0.68	0.14	0.41	Aug 64		
N. H:	Concord	15	0.94	0.14	0.47	Jan 65		
N. J:	Trenton	28	0.87	<0.10	0.48	Apr 64	210	5.4
N. Mex:	Santa Fe	25	0.54	<0.10	0.21	Nov 64	210	9.8
N. Y:	Albany	18	0.93	0.15	0.53	Jul 64	200	3.1
	Buffalo	14	1.23	0.24	0.59	Nov 64		
	New York	23	0.86	<0.10	0.47	Dec 64		
N. C:	Gastonia	29	0.87	<0.10	0.55	Nov 64	250	4.8
N. Dak:	Bismarck	28	0.88	0.12	0.35	Jan 65	200	3.9
Ohio:	Cincinnati	21	0.98	0.14	0.55	Aug 64		
	Columbus	30	1.39	0.17	0.68	Apr 64	400	18.2
	Painesville	28	1.59	0.22	0.79	Oct 64	230	14.4
Okla:	Oklahoma City	28	0.53	<0.10	0.20	Apr 64		
	Ponca City	30	0.46	<0.10	0.16	Oct 64	200	22.3
Ore:	Portland	30	1.54	<0.10	0.45	Oct 64	210	4.4
Pa:	Harrisburg	26	1.02	0.20	0.61	Jul 64	200	5.9
P. R:	San Juan	26	0.42	<0.10	0.15	Mar 64	200	9.8
R. I:	Providence	29	0.99	<0.10	0.41	Jan 64	230	20.7
S. C:	Columbia	30	0.74	<0.10	0.44	Dec 64	200	4.2
S. Dak:	Pierre	29	0.65	<0.10	0.27	Sep 64		
Tenn:	Nashville	29	1.13	<0.10	0.65	Jan 65	230	19.8
Tex:	Austin	28	0.60	<0.10	0.23	Aug 64	210	29.8
	El Paso	28	0.56	<0.10	0.25	Jan 65	200	3.0
Utah:	Salt Lake City	30	1.01	0.22	0.53	Aug 64	660	2.2
Vt:	Barre	30	0.90	0.14	0.51	Sep 64	230	10.6
Va:	Richmond	29	0.76	<0.10	0.45	Sep 64	220	18.4
Wash:	Seattle	30	0.70	<0.10	0.20	Jul 64	200	7.7
	Spokane	27	1.18	<0.10	0.32	[c]—		
W. Va:	Charleston	26	1.32	<0.10	0.65	Dec 64	200	14.8
Wis:	Madison	30	1.02	<0.10	0.44	Sep 64	220	11.8
Wyo:	Cheyenne	30	0.80	<0.10	0.40	Aug 64	1100	5.8
Network summary		1,877	1.59	<0.10	0.39		260	11.5

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values of <0.10 are assumed to be 0.10 for averaging purposes. If the <0.10 values represent more than 10 percent of the average, a less-than sign is placed before the average.
[b] Blank indicates no report received.
[c] Profile scheduled for February 1965.

FIGURE 1.—RADIATION SURVEILLANCE NETWORK SAMPLING STATIONS

time of collection.[1] The daily concentrations and estimated ages of selected samples are reported by the PHS in a monthly RSN report (*1*). The September 1964 average gross beta concentrations in air for RSN stations are given in table 1. Time profiles of gross beta activity in air for eight RSN stations are shown in figure 2.

Precipitation

Continuous sampling for total precipitation is conducted at most stations on a daily basis, using funnels with collection areas of 0.4 square meter. A 500-ml aliquot of the collected precipitation is evaporated to dryness, and the residue is forwarded to the laboratory for analysis. If the collected sample is between 200 and 500 ml, the entire sample is evaporated. When a sample is smaller than 200 ml (equivalent to 0.5 mm or 0.02 inches of rainfall), the volume of precipitation is reported, but no analysis is made.

In the laboratory the gross beta activity in precipitation is determined by counting the evaporated sample by the same method used for analyzing the air filters, including the extrapolation to time of collection. Deposition for the sample is determined by:

$$D = \frac{CP}{1000}$$

where D is the deposition in nc/m^2, C is the concentration in pc/liter, and P is the depth of precipitation in mm. The individual values of deposition and depth of precipitation are totaled for the month, and the average concentration for the month, $\overline{C}$, is determined by:

$$\overline{C} = \frac{\Sigma D}{\Sigma P} \times 1000$$

The September 1964 average concentrations and total depositions are given in table 1.

[1] If a sample contains a mixture of fresh and old fission products, the age estimated by the Way-Wigner formula is some intermediate value and cannot be used for estimating date of formation.

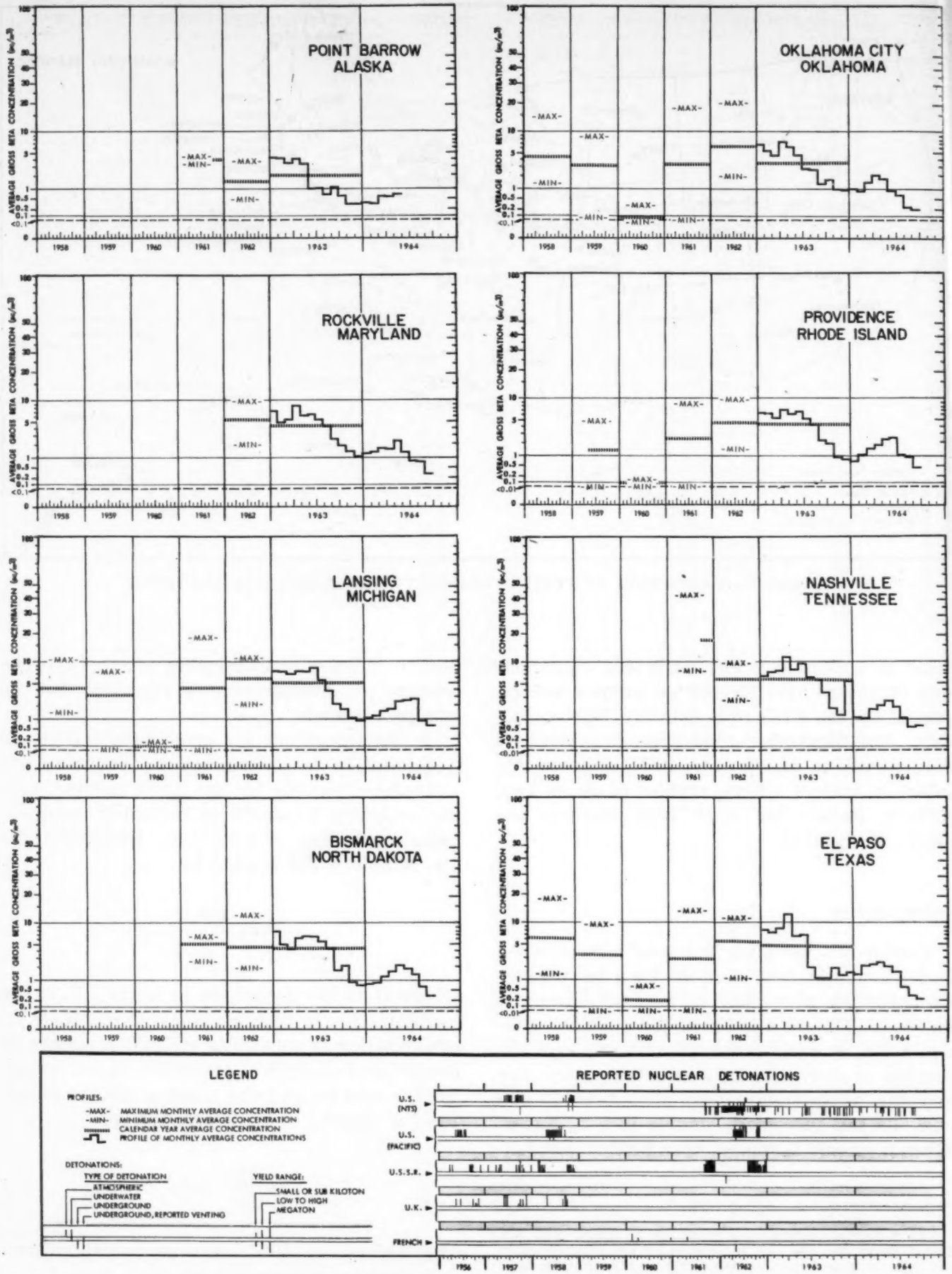

FIGURE 2.—MONTHLY AND YEARLY PROFILES OF BETA ACTIVITY IN AIR—RADIATION SURVEILLANCE NETWORK, 1958–SEPTEMBER 1964

FIGURE 3.—NATIONAL AIR SAMPLING NETWORK STATIONS, 1964

2. National Air Sampling Network Third Quarter 1964

Division of Air Pollution, Public Health Service

The necessity of having basic data on the nature and extent of air pollution throughout the United States led to the organization of the National Air Sampling Network (NASN) in 1953. The NASN analyzes air samples for the total quantity of suspended particulate matter, benzene-soluble organic matter, and gross beta radioactivity. Selected samples are also analyzed for nitrates, sulfates, and a number of metals. These analyses aid in the detection of trends in levels of pollution with respect to time, location, population density, climate, and other factors.

Gross Beta Activity in Air

NASN stations (see figure 3) are manned by cooperating Federal, State and local agencies. The current basic network consists of 110 sampling stations which operate every year in 73 large cities and 37 nonurban areas. In addition, there are stations in 130 cities which operate every other year. Thus, there are 240 sampling stations in all in the NASN network, of which 175 are active in any given year.

Continuous 24-hour samples of suspended particulate matter are taken at each station. The samples, representing approximately 2,000 cubic meters of air, are collected on glass fiber filters on a biweekly random sampling schedule. They are then sent for analysis to the Network laboratory at the Robert A. Taft Sanitary Engineering Center in Cincinnati, Ohio. Third quarter 1964 data appear in table 2.

TABLE 2.—FISSION PRODUCT GROSS BETA ACTIVITY IN SURFACE AIR, NASN, THIRD QUARTER, 1964

[Concentrations in pc/m³]

Station	Number of samples	Maximum	Minimum	Average
Alabama				
Birmingham	7	1.9	0.1	0.6
Gadsden	7	1.9	0.1	0.7
Mobile	7	1.9	0.2	0.7
Alaska				
Anchorage	7	0.6	0.1	0.3
Arizona				
Grand Canyon Park*	7	1.9	0.2	0.7
Maricopa County*	7	1.2	0.1	0.5
Phoenix	7	1.4	0.1	0.5
Tucson	7	0.9	0.1	0.4
Arkansas				
Little Rock	6	0.6	0.2	0.4
Montgomery County*	6	1.2	0.3	0.7
Texarkana	7	1.4	0.1	0.7
California				
Bakersfield	6	2.1	0.6	1.3
Burbank	5	1.0	0.5	0.7
Humboldt County*	7	0.4	0.1	0.2
Los Angeles	7	0.7	0.3	0.5
Monterey	5	0.4	0.2	0.3
Oakland	7	0.6	0.1	0.3
Pasadena	7	1.9	0.4	0.9
Sacramento	7	0.9	0.3	0.6
San Diego	7	0.8	0.3	0.5
San Francisco	7	0.5	<0.1	0.3
Santa Ana	5	0.9	0.3	0.5
Santa Barbara	7	0.6	0.2	0.4
Colorado				
Denver	7	2.1	0.3	0.9
Montezuma County*	7	0.8	0.2	0.4
Connecticut				
Hartford	7	1.6	0.1	0.7
New Haven	7	1.5	0.1	0.7
Delaware				
Kent County*	6	1.8	0.1	0.7
Newark	5	1.4	0.3	0.7
Wilmington	7	1.0	0.3	0.7
District of Columbia	7	1.8	<0.1	0.5
Florida				
Florida Keys*	4	1.0	0.3	0.8
Jacksonville	7	1.8	0.1	0.7
Orlando	4	1.3	0.3	0.8
Tampa	5	0.9	0.1	0.5
Georgia				
Atlanta	7	1.8	0.2	0.7
Hawaii				
Honolulu	7	1.8	0.3	0.7
Idaho				
Boise	7	3.2	0.5	1.6
Butte County*	6	3.7	0.6	1.7
Illinois				
Chicago	5	0.8	0.3	0.5
Cicero	3	1.2	0.4	0.7
Moline	7	1.2	0.2	0.6
Peoria	6	1.5	0.3	0.7
Rock Island	7	2.4	0.3	1.1
Springfield	7	1.0	0.4	0.7
Indiana				
East Chicago	6	1.0	0.3	0.6
Evansville	6	1.0	0.2	0.5
Fort Wayne	7	2.6	0.5	0.9
Gray	6	1.1	0.4	0.8
Indianapolis	7	1.3	0.4	0.8
Lafayette	6	0.9	0.3	0.5
Parke County*	7	0.8	0.6	0.7
Iowa				
Davenport	7	1.7	0.3	0.8
Delaware County*	7	1.6	0.2	0.7
Des Moines	7	2.4	0.2	0.9
Dubuque	7	1.4	0.1	0.7
Kansas				
Kansas City	7	1.2	0.3	0.6
Wichita	7	1.0	0.3	0.6
Kentucky				
Ashland	5	1.3	0.3	0.8
Covington	7	1.1	0.3	0.7
Louisville	5	0.8	0.2	0.5
Louisiana				
Baton Rouge	6	1.6	0.2	0.6
Lake Charles	7	1.3	<0.1	0.4
New Orleans	7	2.2	0.1	0.7
Maine				
Acadia Nat Park*	6	0.5	0.2	0.3
Portland	6	2.0	0.2	0.9
Maryland				
Baltimore	7	1.7	0.2	0.7
Calvert County*	7	2.1	0.2	0.7
Massachusetts				
Boston	7	1.1	0.2	0.6
Springfield	7	1.5	0.1	0.6
Michigan				
Detroit	6	1.9	0.5	1.0
Wyandotte	6	2.8	0.3	1.2
Minnesota				
Duluth	7	2.3	0.2	0.8
Minneapolis	7	1.6	0.1	0.8
Moorhead	7	1.6	0.3	0.9
St Paul	7	1.8	0.1	0.9
Mississippi				
Jackson	6	1.5	0.5	0.8
Jackson County*	7	2.1	0.1	0.6
Missouri				
Kansas City	7	1.7	0.3	0.8
Shannon County*	6	1.2	0.1	0.6
St Louis	7	1.1	0.4	0.6
Montana				
Glacier Natl. Park*	7	1.0	0.3	0.7
Helena	7	4.7	0.1	1.5
Nebraska				
Omaha	7	2.3	0.1	0.9
Thomas County*	6	1.5	0.4	0.8
Nevada				
Las Vegas	7	2.8	0.2	0.9
White Pine County*	6	3.2	0.4	1.0
New Hampshire				
Concord	7	1.4	0.1	0.5
Coos County*	5	1.0	0.1	0.5
New Jersey				
Bridgeton	6	1.4	<0.1	0.6
Camden	7	1.8	0.4	0.8
Jutland	4	1.4	0.6	0.9
Marlton	6	3.6	0.2	1.1
Newark	7	1.6	0.2	0.7
New Brunswick	7	1.5	0.1	0.7
Pemberton	6	0.7	<0.1	0.5
Perth Amboy	5	1.2	<0.1	0.7
Princeton	5	1.0	0.4	0.7
Trenton	6	1.5	0.1	0.6
Glassboro	7	1.8	0.2	0.6
New Mexico				
Albuquerque	7	0.9	0.1	0.4
Rio Arriba County*	7	0.8	0.3	0.6
New York				
Cape Vincent*	7	2.0	0.3	0.8
New York	6	1.5	0.3	0.8
North Carolina				
Cape Hatteras*	6	2.1	0.1	0.6
Charlotte	7	1.6	0.1	0.5
Fayetteville	6	2.0	0.1	0.6
Winston Salem	6	0.5	0.2	0.3
North Dakota				
Bismarck	7	1.6	0.2	0.9
Fargo	7	2.5	0.3	1.0
Ward County*	7	1.7	0.2	0.7
Ohio				
Akron	7	1.8	0.1	0.9
Cincinnati	6	1.1	0.3	0.7
Cleveland	7	1.7	0.2	0.8
Columbus	7	1.8	0.2	0.7
Dayton	7	1.8	0.4	0.8
Lorain	7	0.9	0.2	0.6
Steubenville	7	1.4	0.1	0.6
Toledo	7	1.5	0.1	0.6
Youngstown	7	2.3	0.1	0.8
Oklahoma				
Cherokee County*	7	0.9	0.2	0.5
Oklahoma City	5	1.0	0.2	0.6
Tulsa	7	1.2	0.1	0.7
Oregon				
Curry County*	5	0.4	0.1	0.2
Portland	6	0.7	0.3	0.4
Pennsylvania				
Clarion County*	5	1.2	0.3	0.6
Embreeville	7	0.8	0.3	0.4
Lancaster	6	2.0	0.1	1.0
Philadelphia	7	1.8	<0.1	0.7
Pittsburgh	7	2.4	0.1	0.8
West Chester	4	1.0	0.2	0.5
Puerto Rico				
Guayanilla	7	0.8	0.1	0.4
Ponce	7	1.0	0.1	0.4
San Juan	7	1.0	0.1	0.4
Rhode Island				
Providence	5	1.2	<0.1	0.7
Washington County*	7	1.3	0.1	0.6
South Carolina				
Columbia	5	2.1	0.4	0.9
Richland County*	6	1.7	0.2	0.6
South Dakota				
Black Hills*	7	1.7	0.4	1.0
Sioux Falls	7	2.0	0.1	0.9
Tennessee				
Chattanooga	6	1.6	0.3	0.8
Memphis	7	1.2	0.1	0.7
Nashville	7	1.1	<0.1	0.7
Texas				
Aransas County*	7	1.0	<0.1	0.4
Dallas	7	1.3	0.1	0.5
El Paso	7	0.6	0.1	0.4
Houston	7	1.3	<0.1	0.5
Laredo	6	0.7	0.1	0.3
San Antonio	7	1.3	0.2	0.5
Texarkana	7	1.2	0.1	0.6
Waco	7	1.4	0.2	0.5
Utah				
Ogden	7	2.5	0.4	1.0
Salt Lake City	6	1.5	0.3	0.8
Vermont				
Burlington	5	1.7	0.3	0.7
Orange County*	7	1.5	0.1	0.7
Virginia				
Danville	7	2.3	0.2	0.7
Norfolk	7	2.0	0.2	0.7
Shenandoah Park*	6	1.5	0.3	0.6
Washington				
Seattle	7	0.8	0.1	0.3
Tacoma	7	0.9	0.1	0.3
West Virginia				
Charleston	7	2.1	0.1	0.8
Huntington	7	1.4	<0.1	0.7
Parkersburg	7	1.8	0.1	0.7
Weirton	7	2.1	0.2	0.9
Wisconsin				
Door County*	5	0.9	0.2	0.5
Eau Claire	7	1.4	0.4	0.8
Milwaukee	6	0.9	0.3	0.6
Racine	7	1.9	0.2	0.7
Superior	7	2.1	0.1	0.7
Wyoming				
Cheyenne	7	1.4	0.4	0.8
Yellowstone Park*	7	1.7	0.5	1.1

*Nonurban Stations

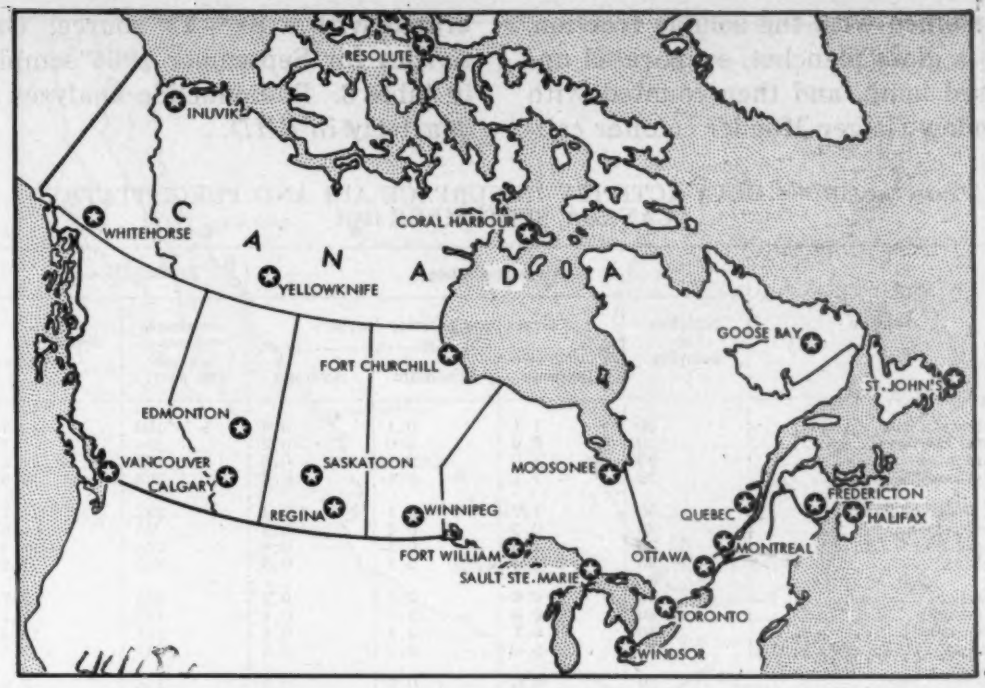

FIGURE 4.—CANADIAN AIR AND PRECIPITATION SAMPLING STATIONS

3. Canadian Air Monitoring Program [2] September 1964

Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (see figure 4), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of the National Health and Welfare (*3–7*).

Air

Each air sample involves the collection of particulates from about 650 cubic meters of air drawn through a high-efficiency 4-inch-diameter glass fiber filter during a 24-hour period. These filters are sent daily to the Radiation Protection Division Laboratory in Ottawa. At the laboratory, a 2-inch-diameter disk is cut from each filter and counted with a thin-end-window, gas-flow, Geiger-Mueller counter system, calibrated with a Sr^{90}–Y^{90} standard. Four successive measurements are made on each filter to permit correction for natural activities and for the decay of short-lived fission products. The results are extrapolated to the end of the sampling period. Canadian air data for September 1964 are given in table 3 and presented in conjunction with U. S. and Mexican data by an isogram map (figure 6).

Precipitation

The amount of radioactive fallout deposited on the ground is determined from measurements on material collected in special polyethylene-lined rainfall pots. The collection period for each sample is one month. After transfer of the water to the sample container, the polyethylene liner is removed, packed with the sample, and sent to the laboratory.

Strontium and cesium carriers are added to all samples on arrival at the laboratory. Other carriers are also added to selected samples according to the specific radionuclides to be determined. The samples are then filtered and the filtrate evaporated to near dryness. The filter paper containing insoluble matter is ignited together with the polyethylene liner at 450° C.

[2] Data from *Radiation Protection Programs 10:* 11–24, Radiation Protection Division Canadian Department of National Health and Welfare, Ottawa, Canada (October 1964).

The ash is combined with the soluble fraction, transferred to a glass planchet, evaporated under an infra-red lamp, and then counted with a thin-end-window Geiger-Mueller counter calibrated with a Sr^{90}–Y^{90} source. Gross beta activities for September 1964 samples are given in table 3. Radionuclide analyses are reported quarterly in *RHD*.

TABLE 3.—GROSS BETA ACTIVITY IN SURFACE AIR AND PRECIPITATION, CANADA, SEPTEMBER 1964

Station	Air surveillance				Precipitation data	
	Number of samples	Gross beta activity (pc/m³)			Average concentration (pc/liter)	Total deposition (nc/m²)
		Maximum	Minimum	Average		
Calgary	30	1.1	0.1	0.4	186	10.7
Coral Harbour	29	0.9	0.0	0.2	294	8.3
Edmonton	30	1.0	0.1	0.3	172	11.2
Ft. Churchill	29	1.1	0.1	0.3	208	11.9
Ft. William	30	1.1	0.1	0.4	233	14.7
Fredericton	30	0.5	0.1	0.3	90	6.9
Goose Bay	30	1.0	0.1	0.4	226	12.5
Halifax	30	1.0	0.1	0.3	102	11.5
Inuvik	30	0.8	0.1	0.3	234	2.7
Montreal	30	0.8	0.1	0.4	247	8.1
Moosonee	30	0.7	0.1	0.3	213	18.4
Ottawa	30	0.6	0.1	0.4	307	9.0
Quebec	29	0.6	0.1	0.3	266	8.6
Regina	28	0.8	0.1	0.4	188	8.7
Resolute	30	0.6	0.0	0.2	3,752	28.6
St. John's, Nfld	27	0.5	0.1	0.2	111	13.4
Saskatoon	30	0.9	0.1	0.3	395	19.3
Sault Ste. Marie	30	0.9	0.1	0.3	173	15.9
Toronto	30	1.1	0.1	0.4	390	4.2
Vancouver	30	1.1	0.1	0.3	153	18.5
Whitehorse	30	1.0	0.1	0.4	451	6.2
Windsor	22	0.7	0.1	0.4	181	11.5
Winnipeg	30	0.7	0.1	0.4	326	11.5
Yellowknife	30	1.2	0.1	0.3	179	9.5
Network summary	704	1.2	0.1	0.3	378	11.7

4. Mexican Air Monitoring Program September 1964

National Commission of Nuclear Energy

The Radiation Surveillance Network of Mexico was established by the *Comisión Nacional de Energia Nuclear* (CNEN), Mexico City. From 1952 to 1961 the network was directed by the Institute of Physics of the University of Mexico, under contract to the CNEN (*8–12*).

In 1961 the CNEN appointed its Division of Radiological Protection (DRP) to establish a new Radiation Surveillance network. This network consists of 17 stations (see figure 5), twelve of which are located at airports and operated by airline personnel. The remaining five stations are located at Mexico City, Mérida, Veracruz, San Luis Potosí, and Ensenada. Staff members of the DRP operate the station at Mexico City while the other four stations are manned by members of the Centra de Previsión del Golfo de México, the Chemistry Department of the University of Mérida, the Institute de Zonas Desérticas of the University of San Luis Potosí, and the Escuela Superior de Ciencias Marinas of the University of Baja California, respectively.

Sampling

The sampling procedure involves drawing air for 24 hours a day, 3 or 4 days a week at the rate of approximately 1,200 cubic meters per day, through a high-efficiency, 6 x 8-inch glass fiber filter, using high volume samplers. After each 24-hour sampling period, the filter is removed and forwarded via air mail to the "Laboratorio de Estudios sobre Contaminación Radioactiva," CNEN, in Mexico City for assay of gross beta activity. A minimum of 3 or 4

FIGURE 5.—FALLOUT NETWORK SAMPLING STATIONS IN MEXICO

days after collection is allowed for decay of radon and thoron daughter natural radioactivity. Data are not extrapolated to time of collection.

Results

The maximum, minimum, and average fission product beta concentrations in surface air during September 1964 are presented in table 4. The data are also represented in the beta activity isogram map of North America, figure 6.

TABLE 4.—GROSS BETA ACTIVITY OF AIRBORNE PARTICULATES AT SELECTED SAMPLING LOCATIONS IN MEXICO, SEPTEMBER 1964

Station	Number of Samples	[Concentrations in pc/m³]		
		Maximum	Minimum	Average
Acapulco	3	0.1	0.1	0.1
Ciudad Juárez	21	0.9	0.1	0.2
Chihuahua	21	0.5	0.1	0.2
Ensenada	6	0.4	0.1	0.3
Guadalajara	[a] 1	0	0	0
Guaymas	18	0.7	0.1	0.3
La Paz	10	0.7	0.2	0.4
Matamoros	18	0.2	0.1	0.1
Mazatlán	4	0.2	0.1	0.1
Mérida	18	0.3	0.1	0.1
México, D.F.	19	0.2	0.1	0.1
Nuevo Laredo	11	0.2	0.1	0.1
San Luis Potosí	9	0.2	0.1	0.1
Tampico	12	0.4	0.1	0.1
Torreón	22	0.2	0.1	0.1
Tuxtla Gutiérrez [b]	—	—	—	—
Veracruz	10	0.1	0.1	0.1
Network Summary	203	0.9	0.1	0.2

[a] No analysis made.
[b] Temporarily shut down.

5. Pan American Air Sampling Program September 1964

Pan American Health Organization and Public Health Service

Gross beta activity in air is monitored by four countries in the Americas under the auspices of a collaborative program developed by the Pan American Health Organization and the Public Health Service (PHS) for assisting countries of the Americas in developing radiological health programs. The sampling equipment and analytical services are provided by the Division of Radiological Health, PHS, and are identical with those employed for the Radiation Surveillance Network.

The four air sampling stations included in the program are operated by the technical staff of the Ministry of Health in each country. The station in Kingston, Jamaica, is operated by the Public General Hospital; in Caracas, Venezuela, by the Venezuelan Institute for Scientific Investigations; in Lima, Peru, by the Institute of Occupational Health; and in Santiago, Chile, by the Occupational Health Service. The Kingston station began operation in March 1964, and the other three were started near the end of 1962.

The September 1964 air monitoring results from the four participating countries are given in table 5.

TABLE 5.—GROSS BETA ACTIVITY IN AIR, SEPTEMBER 1964

[Concentrations in pc/m³]

Sampling stations	No. of samples	Maximum	Minimum	Average *
Kingston, Jamaica	3	0.29	0.17	0.21
Caracas, Venezuela	22	0.29	<0.10	0.11
Lima, Peru	21	0.20	<0.10	0.13
Santiago, Chile	29	0.27	<0.10	0.15

* The monthly average is calculated by weighting the individual samples with length of sampling period. Values of <0.10 are assumed to be 0.10 for averaging purposes. If the <0.10 values represent more than 10 percent of the average, a less-than sign is placed in front of the average.

6. Gross Beta Activity in Air, North America September 1964

Beginning with January 1963 data, monthly average concentrations of airborne gross beta activity in Canada and the United States have been presented in combined form as isogram maps of most of North America. The data from the Radiation Surveillance Network and the Canadian Air Network were adjusted to each other by means of an intercalibration factor derived by Lockhart and Patterson (*13*).

With the formation of the Mexican Air monitoring program, new intercalibration ratios were determined, this time including the Canadian Network, Radiation Surveillance Network, Pan American Air Sampling Program, National Air Sampling Network, the HASL 80th Meridian Network, and the Mexican Network (*14*). The new intercalibration factors reflect some changes in standardization in both the RSN and the Canadian Air Network, effective September 1963.

Figure 6 shows the September 1964 activity in air throughout North America based on the data from the Canadian Air Monitoring Program, the Radiation Surveillance Network, the Pan American Air Sampling Program, and the Mexican Air Monitoring program. An intercalibration factor of 1.28 was applied to the RSN and Pan American data, and the Mexican data were multiplied by 0.81 in order to adjust them to Canadian data.

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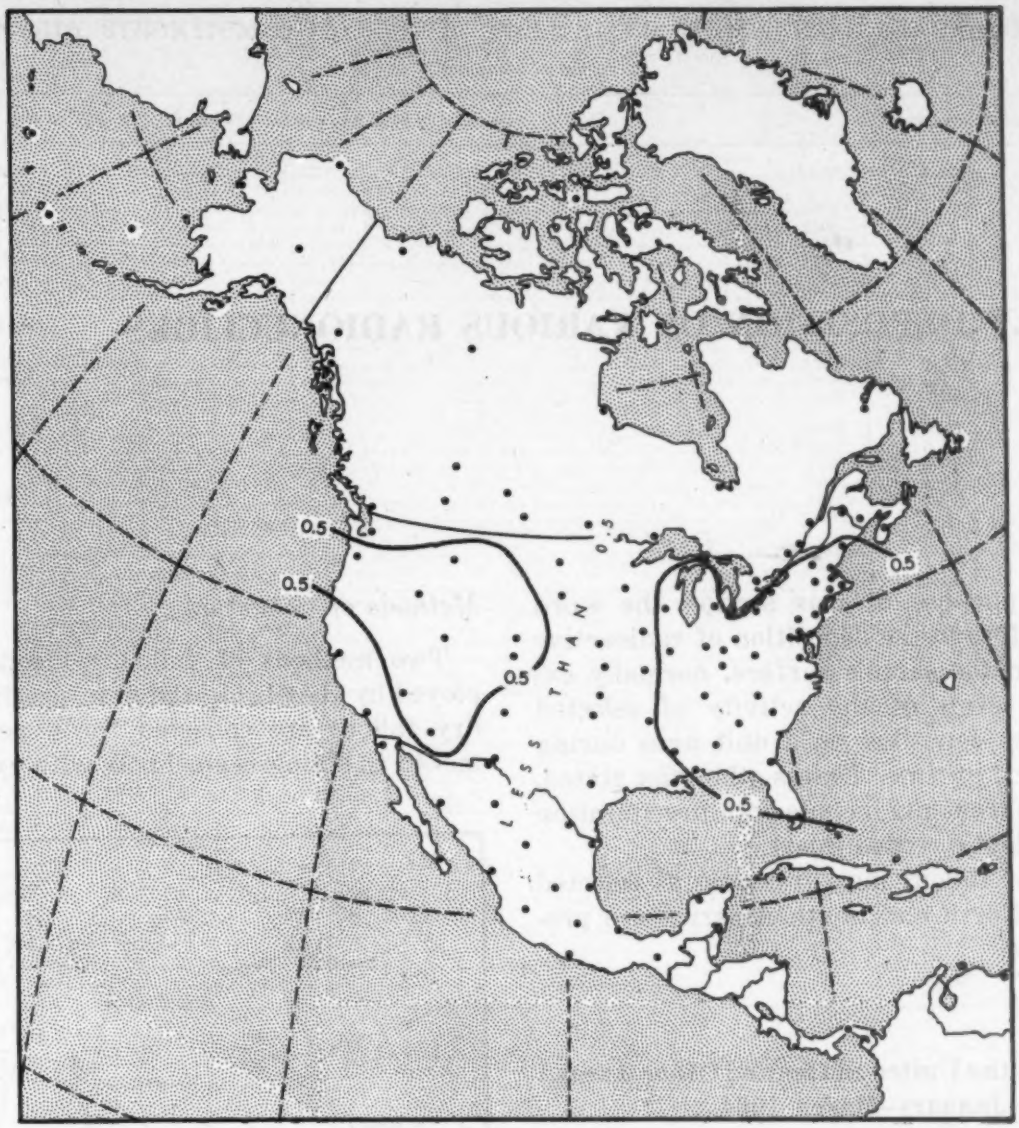

FIGURE 6.—ISOGRAMS OF AVERAGE GROSS BETA CONCENTRATIONS IN AIR THROUGHOUT NORTH AMERICA (pc/m³) SEPTEMBER 1964

(*13*) Lockhart, L. B., Jr. and R. L. Patterson, Jr.: *Intercalibration of Some Systems Employed in Monitoring Fission Products in the Atmosphere, NRL Report 5850,* Naval Research Laboratory, Washington, D. C. 20390 (November 13, 1962); abstracted in *Radiological Health Data,* December 1962.

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MONTHLY DEPOSITION OF VARIOUS RADIONUCLIDES

For the purpose of this section the word "fallout" refers to the deposition of radioactive materials on the earth's surface, normally expressed in terms of the activity of selected radionuclides deposited on a unit area during a given period of time. Unless otherwise stated, fallout measurements include both precipitation and dry fallout (settled dust).

Reports of fallout measurements at selected stations in North and South America are presented below.

1. Fallout in the United States and Other Areas,[1] January–March 1964

Health and Safety Laboratory
Atomic Energy Commission

Monthly fallout deposition rates are determined by the Health and Safety Laboratory (HASL) for 49 sites in the United States and 107 locations in other countries. HASL data from 38 of the U. S. stations and 24 other selected points in the Western Hemisphere (see figure 1) covering the period from January through March 1964 are summarized below. All the stations of the 80th Meridian Network, except Washington, D. C., are represented.

[1] The data in this article were taken from *Fallout Program Quarterly Summary Report, HASL–149:* 1–29, Health and Safety Laboratory, AEC, New York, N.Y. 10014.

Methods of Collection

Two methods of fallout collection are employed by HASL. In the first, precipitation and dry fallout are collected for a period of one month in stainless steel pots with exposed areas

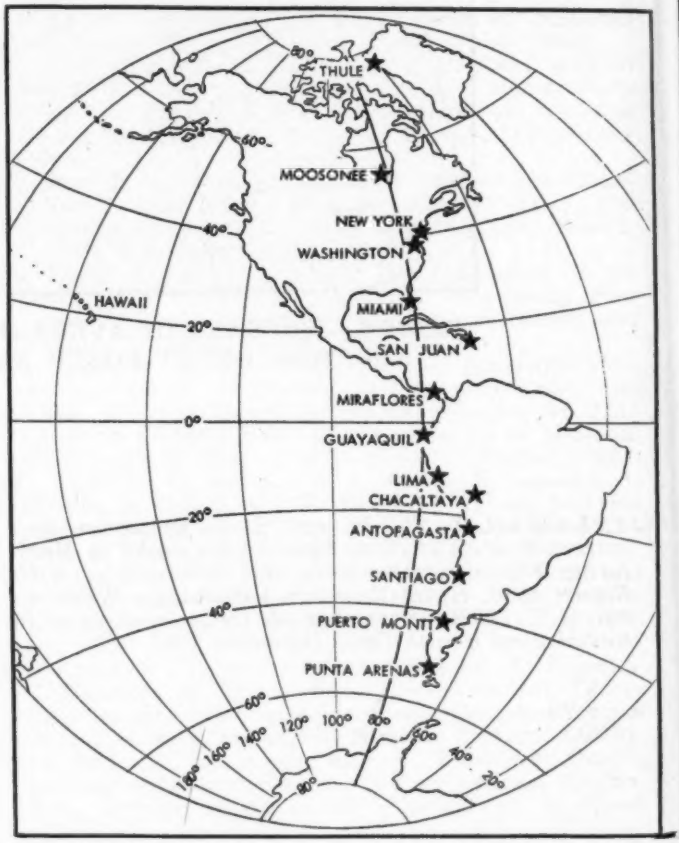

FIGURE 1.—80th MERIDIAN NETWORK SAMPLING STATIONS

TABLE 1.—MONTHLY STRONTIUM-90 FALLOUT IN THE UNITED STATES, HASL, JANUARY-MARCH 1964

[Deposition in nc/m²]

	Sampling location and type of collection	January	February	March
Ala:	Birmingham (pot)	0.91	2.39	1.58
Alaska:	Anchorage (col)	0.16	0.22	0.39
	Barrow (col)	[a]	[a]	[a]
	Cold Bay (col)	0.60	0.46	0.51
	Fairbanks (col)	0.06	0.11	0.07
	Juneau (col)	0.85	1.57	1.24
	Nome (col)	[a]	[a]	0.07
Calif:	W. Los Angeles (pot)	0.20	0.04	0.78
	Palo Alto (pot)	0.78	0.11	0.46
	Palo Alto (col)	0.77	0.10	0.40
	San Francisco (col)	0.72	0.14	0.54
Colo:	Denver (col)	0.09	0.19	0.22
Fla:	Coral Gables (pot)	0.75	0.39	0.12
	Miami (col)	0.19	0.47	0.19
Hawaii:	Hilo (col)	3.09	3.16	5.22
	Litlue (col)	1.62	0.15	1.33
	Mauna Loa (col)	0.12	0.10	0.31
	Oahu (pot)	0.41	0.69	1.78
Ill:	Argonne (pot)	0.29	0.13	1.29
La:	New Orleans (col)	1.96	1.20	1.27
Minn:	International Falls (col)	0.07	0.17	0.18
Mo:	Columbia (col)	0.47	0.41	1.30
Mont:	Helena (col)	0.15	0.17	0.05
N.J:	Westwood (pot)	1.04	0.42	1.35
	Westwood (col)	0.53	0.53	1.35
N.Y:	New York (pot)	1.04	2.10	1.83
N.Dak:	Williston (col)	0.30	0.02	0.05
Ohio:	Wooster (pot)	1.11	0.54	1.54
Okla:	Tulsa (pot)	0.22	[b]	[b]
Ore:	Medford (col)	0.61	0.19	0.51
S.C:	Columbia (col)	0.34	1.47	1.70
S.Dak:	Vermillion (pot)	0.14	0.15	0.60
Texas:	Dallas (col)	0.51	1.08	1.56
	El Paso (col)	0.47	0.05	0.69
	Houston (col)	0.36	1.40	0.54
Utah:	Salt Lake City (pot)	0.84	0.41	1.78
Va:	Sterling (U.S. Weather Bureau Station) (col)	[c]1.52	[c]2.04	[c]2.02
Wash:	Seattle (pot)	1.20	0.81	0.97
	Tatoosh Island (col)	2.69	1.32	2.17
Wis:	Green Bay (col)	0.52	0.07	0.52

[a] Not received
[b] No report
[c] Average of 2 collections

of 0.076m². At the end of the collection period, the contents are transferred, by careful scrubbing with a rubber spatula, to a polyethylene sample bottle which is then shipped to the laboratory for analysis.

The second method involves the use of a polyethylene funnel, with exposed area of 0.07m² attached to an ion exchange column. After a one-month collection, the inside of the funnel is wiped with a tissue, and the tissue is inserted in the end of the column, which is then sealed and sent to HASL for analysis. It has been shown that at the 95 percent confidence level there was no significant difference in the strontium–90 measurements obtained from samples collected by the two methods (*1*).

Strontium–90

All of the HASL fallout samples—both pot and column—were assayed for strontium–90. The strontium–90 data are given in tables 1 and 2 for 58 selected stations. Where duplicate samples were collected, the average values are given.

Other Radionuclides

Laboratories at Westwood, New Jersey; Chattanooga, Tennessee; Seattle, Washington; Appleton, Wisconsin; Palo Alto, California; and Midwest City, Oklahoma, have analyzed monthly pot samples for various radionuclides. The monthly depositon rates for Sr^{89}, Sr^{90}, Ce^{144}, Cs^{137}, Zr^{95}, Mn^{54}, and precipitation depth are presented in table 3.

TABLE 2.—MONTHLY STRONTIUM-90 FALLOUT IN NORTH AND SOUTH AMERICA, HASL, JANUARY-MARCH 1964

[Deposition in nc/m²]

Station and type of collection		January	February	March
Bermuda:	(Kindley AFB) (col)	1.13	1.44	0.66
Bolivia:	La Paz (col)	0.03	0.03	0.03
Brazil:	Belem (col)	0.18	0.94	0.07
	Trinidade Island (col)	0.12	0.07	[a]
Canada:	Ontario, Moosonee [b] (col)	0.43	0.14	0.10
	Ernest Harmon AB (col)	0.05	0.37	0.34
	Goose Bay AB (col)	0.05	0.14	[a]
Chile:	Antofagasta [b] (col)	0.03	0.02	0.01
	Puerto Montt [b] (col)	0.02	0.14	0.16
	Punta Arenas [b] (col)	0.05	0.09	[a]
	Santiago [b] (pot)	0.01	1.10	[a]
	Santiago (col)	0.05	0.03	0.01
Colombia:	Bogota (pot)	0.03	[a]	[a]
Costa Rica:	Turrialba (col)	0.17	0.17	0.11
Equador:	Guayaquil [b] (col)	0.08	0.08	0.79
	Quito (col)	[c]	0.05	0.01
Greenland:	Thule [b] (col)	0.10	0.05	0.02
Iceland:	Keflavik (col)	[d]0.38	1.04	0.75
Mexico:	Mexico City (col)	0.07	[a]	[a]
Canal Zone	(col)	0.08	0.17	0.03
Peru:	Lima (col)	[e]0.04	[e]0.02	[e]
	Lima [b] (col)	0.19	0.01	0.02
Puerto Rico:	San Juan (col)	0.26	0.29	0.41
Venezuela:	Caracas (col)	[f]0.52	[f]0.04	[f]0.11

[a] Not reported
[b] 80th Meridan Network Station
[c] Not received
[d] (1/11–31)
[e] Mid-month collections
[f] Average of 2 collections

TABLE 3.—RADIOCHEMICAL ANALYSES OF POT FALLOUT SAMPES AT 6 U.S. SITES, HASL, JANUARY-MARCH 1964

Sampling location by State and city	Fission Product and "Tracer" Radionuclides in Monthly Collections (Deposition in nc/m²)																				
	Precipitation(mm)			Strontium-89			Strontium-90			Cerium-144			Cesium-137			Zirconium-95			Manganese-54		
	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar
California, Palo Alto	86.6	6.35	35.3	0.17	0.03	[a]	0.74	0.10	[a]	6.52	3.31	6.68	0.90	0.33	0.69	10.5	1.4	0.18	0.90	0.12	0.32
New Jersey, Westwood	88.4	48.0	56.9	0.26	0.07	0.08	1.04	0.42	1.35	22.3	7.14	19.0	2.00	0.95	2.50	1.60	0.42	1.03	2.07	0.49	1.47
Oklahoma, Midwest City	17.0	50.3	34.0	0.03	0.18	[a]	0.18	1.03	[a]	2.38	14.6	12.4	0.26	1.72	1.88	4.67	5.33	0.13	0.14	1.09	1.41
Tennessee, Chattanooga	143.0	139.7	289.6	0.35	0.33	0.08	1.29	1.85	1.88	19.8	28.0	36.3	2.02	4.01	4.79	2.12	1.68	[b]	1.38	2.43	1.94
Washington, Seattle	187.7	31.8	75.4	0.25	0.09	0.04	1.51	0.57	1.41	19.1	7.53	12.6	2.12	0.94	1.87	1.15	0.86	0.66	1.71	0.73	1.38
Wisconsin, Appleton	26.4	4.06	42.2	0.13	0.04	0.13	0.59	0.12	0.82	9.92	2.09	9.65	1.05	0.25	1.50	0.93	0.15	0.61	0.85	0.18	0.91

[a] No report
[b] Lost

FISSION PRODUCT GAMMA ACTIVITY IN SURFACE AIR—80TH MERIDIAN AND U.S. LOCATIONS

Edward P. Hardy, Jr.[1]

80TH MERIDIAN NETWORK MAY AND JUNE 1964

Fourteen air sampling stations near the 80th Meridian (West) from Thule, Greenland, to Punta Arenas, Chile, make up the Health and Safety Laboratory (HASL) 80th Meridian Network (figure 1). An additional station at Mauna Loa, Hawaii, is included for comparing data with that from Chacaltaya, Bolivia; both are at a high elevation and their respective latitudes north and south are nearly equal.

Air particulates are sampled on 8-inch-diameter polystyrene (Microsorban) filters, drawing air through the filters continuously at the rate of about 1,400 cubic meters per day. Filters are changed on the 1st, 8th, 15th, and 22nd of each month and forwarded to HASL for analysis. A total gamma count over the energy range, 0–3 Mev, is made approximately

[1] Mr. Hardy is a chemist on the staff of the Environmental Studies Division, Health and Safety Laboratory, U. S. Atomic Energy Commission.

TABLE 1.—GAMMA ACTIVITY IN SURFACE AIR 80TH MERIDIAN NETWORK, MAY AND JUNE 1964

[Activity in gamma photons/min/m³]

Station latitude, elevation	May sampling periods				May average	June sampling periods				June average
	1–7	8–14	15–21	22–30		1–7	8–14	15–21	22–30	
Thule, Greenland 77° N, 259 m	0.923	1.02	1.42	0.656	0.972	0.510	0.902	0.351	0.194	0.470
Moosonee, Canada 51° N, 10 m	1.64	0.647	0.938	0.706	0.950	0.663	1.32	0.924	1.39	1.08
New York, N.Y. 41° N, 38 m	2.14	1.83	1.65	1.42	1.54	2.17	1.68	lost	1.11	1.56
Washington, D.C. 39° N, 82 m	1.51	1.76	1.49	1.62	1.60	1.58	1.67	1.34	1.18	1.42
Miami, Fla. 26° N, 4 m	0.724	1.58	1.09	0.889	1.05	0.145	0.829	0.585	0.442	0.495
Mauna Loa, Hawaii 19° N, 3394 m	1.32	1.99	0.770	0.638	1.11	0.372	0.419	0.590	0.488	0.469
San Juan, P.R. 18° N, 10 m	0.856	0.950	0.939	0.604	0.823	0.601	0.594	0.551	0.278	0.488
Miraflores, Canal Zone 9° N, 10 m	0.269	0.717	0.738	0.108	0.419	0.0123	0.0443	0.0659	0.0259	0.0364
Guayaquil, Ecuador 0°–08′ S, 7 m	0.0235	0.0278	0.0370	0.0275	0.0289	0.0358	0.0319	0.0205	0.0199	0.0265
Lima, Peru 12° S, 50 m	0.0464	0.0407	0.0287	0.0408	0.0401	0.0464	0.0543	0.0485	0.0553	0.0513
Chacaltaya, Bolivia 17° S, 5220 m	0.0602	0.0586	0.00493	0.0702	0.0603	0.0812	0.0406	0.0462	0.0770	0.0618
Antofagasta, Chile 24° S, 519 m	0.0459	0.0526	0.0435	0.0407	0.0452	0.0638	0.0475	0.0894	0.0781	0.0696
Santiago, Chile 33° S, 5 m	0.0541	0.0443	0.0530	0.0344	0.0458	0.0312	0.0179	0.0480	0.0244	0.0288
Puerto Montt, Chile 41° S, 5 m	0.0191	0.0430	0.0554	0.0405	0.0396	0.0184	0.0251	0.0174	0.0173	0.0193
Punta Arenas, Chile 53° S, 3 m	0.0505	0.0504	0.0408	0.0411	0.0454	0.0101	0.0141	0.0163	0.0154	0.0141

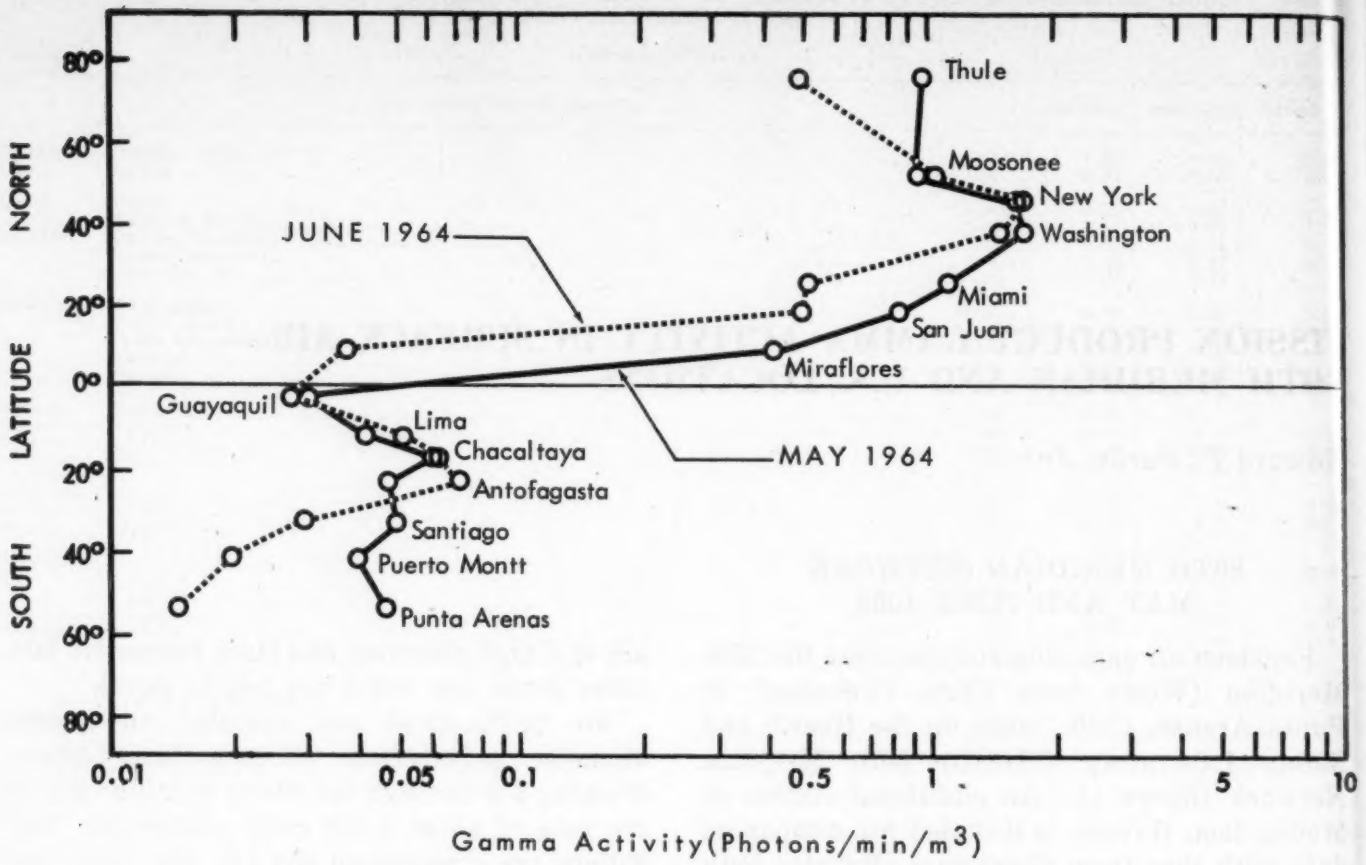

FIGURE 2.—PROFILE OF SURFACE AIR GAMMA ACTIVITY, MAY AND JUNE 1964

two weeks after the end of the sampling period, using an 8 x 4-inch sodium iodide (thallium-activated) crystal. The filters are then composited on a monthly basis and analyzed radiochemically, together with monthly ground deposition samples taken at the same site, for detectable fission and neutron activation products.

The results of total gamma activity determinations in weekly ground level air filter samples taken at 80th Meridian stations during May and June 1964 are listed in table 1, together with average monthly activity concentrations calculated for each site. The average monthly activities are also plotted in figure 2 as activity-latitude profiles.

The May and June averages for all of the northern sites were 1.1 and 0.75 γ/min/m^3, respectively. The corresponding averages in the Southern Hemisphere were 0.044 and 0.039 γ/min/m^3.

Section II—Milk and Food

MILK SURVEILLANCE

Although milk is only one of the many sources of dietary intake of radionuclides, it is the single food item most often used as an indicator of the population's intake of radionuclides from the environment. This is because fresh milk is consumed by a large segment of the United States population and contains most of the radionuclides occurring in the environment which have been identified as biologically important. In addition, milk is produced and consumed on a regular basis, is convenient to handle, is easily analyzed, and samples which are representative of milk consumption in any area can be readily obtained.

1. Pasteurized Milk Network, September 1964

Division of Radiological Health and Division of Environmental Engineering and Food Protection, Public Health Service

The Public Health Service pasteurized milk surveillance program had its origin in a raw milk monitoring network (*1*) established by the Service in 1957. One of the primary objectives of the raw milk network was the development of methods for milk collection and radiochemical analysis suitable for larger scale programs.

Experience derived from this earlier network led to the activation of a pasteurized milk sampling program with stations selected to provide nationwide surveillance of milk production and consumption areas. The present network, which consists of 63 stations, has at least one station in every State, the Canal Zone, and Puerto Rico.

Sampling Procedure

Through the cooperation of State and local milk sanitation authorities, samples are routinely collected at each station. The method specifies that an individual station's sample be composited of subsamples from each milk processing plant in proportion to the plant's average sales in the community served. At most stations the sample represents from 80 to 100 percent of the milk processed. Prior to September 15, 1961, the composite sample was taken from one day's sales per month and was as representative of the community's supply as could be achieved under practical conditions. Beginning with the resumption of nuclear weapons testing in the atmosphere in September 1961, and continuing through January 1963, samples were collected twice a week at nearly all stations and daily for short periods at selected stations. Since then, the sampling frequency has been reduced to once a week.

Samples are preserved with formaldehyde and are sent to the PHS Southwestern (SWRHL), Southeastern (SERHL), or Northeastern Radiological Health Laboratories (NERHL) for analysis. Gamma analyses for iodine–131 are made within 3 to 6 days after sample collection, and any results exceeding 100 pc/liter are immediately telephoned to State health officials for possible public health action. Analytical results are normally available 6 to 7 weeks after monthly samples are received by the laboratories; publication in *RHD* follows 3 to 4 months after the monthly samples are composited for analyses.

Analytical Procedures

Iodine–131, cesium–137, and barium–140 concentrations are determined by gamma scintillation spectroscopy.[1] After the weekly samples are gamma scanned, samples from two consecutive weeks are composited and analyzed radiochemically for strontium–89 and strontium–90. There is an inherent statistical variation associated with all measurements of radionuclide concentrations. With the low radionuclide levels which are usually found in milk and other environmental samples, this variation on a percentage basis is relatively high. The variation depends upon such factors as the method of chemical analysis, the sample counting rate and counting time, interferences from other radionuclides, and the background count. For milk samples, counting times of 50 minutes for gamma spectroscopy and 30 to 50 minutes for beta determinations are used. Table 1 shows the approximate total analytical error (including counting error) associated with radionuclide concentrations in milk. These errors were determined by comparing results of a large number of replicate analyses. The minimum detectable concentration is defined as the measured concentration at which the two-standard-deviation analytical error is equal to the measurement. Accordingly, the minimum detectable concentrations in units of pc/liter are Sr^{89}, 5; Sr^{90}, 2; Cs^{137}, 10; Ba^{140}, 10; and I^{131}, 10. At these levels and below, the counting error comprises nearly all of the analytical error.

[1] Southeastern Radiological Health Laboratory employs a radiochemical procedure for barium–140 analysis.

TABLE 1.—ANALYTICAL ERRORS ASSOCIATED WITH ESTIMATED CONCENTRATIONS FOR SELECTED RADIONUCLIDES IN MILK

Nuclide	Estimated concentration (pc/liter)	Error [a] (pc/liter)	Estimated concentration (pc/liter)	Error [a] (percent of concentration)
Iodine-131	0 to 100	±10	100 or greater	±10
Barium-140	0 to 100	±10	100 or greater	±10
Cesium-137	0 to 100	±10	100 or greater	±10
Strontium-89	0 to 50	±5	50 or greater	±10
Strontium-90	0 to 20	±2	20 or greater	±10

[a] Two standard deviations (2σ).

Calcium analyses at SERHL are done by an ion exchange and permanganate titration method, while at NERHL and SWRHL an ethylenediaminetetraacetic acid (EDTA) method is used. Stable potassium concentrations are estimated from the potassium–40 concentrations[2] determined from the gamma spectrum.

Data Presentation

Table 2 presents summaries of the analyses for September 1964 (Aug. 30–Sept. 26). Although not shown in table 2, the iodine–131 and barium–140 monthly average concentrations in milk were less than 10 pc/liter. Radionuclide values reported by a laboratory as being below the minimum detectable concentration have been averaged by using one-half the minimum detectable value. The averaging procedure was modified for iodine–131 and barium–140 in October 1963 when nondetectable concentrations of these radionuclides were considered zero. A similar procedure is used for the network average.

Figures 1 and 2 are isogram maps showing the estimated strontium–90 and cesium–137 concentrations in milk over the entire country. The value printed beside each station is the monthly average concentration for that station. The isograms were developed by arbitrary interpolation between values for the individual stations. Additional modifications to the isograms are made according to available information on milksheds.

In order to develop the distribution of the network's stations *versus* radionuclide concentrations in milk, tables 3 and 4 have been prepared using monthly averages.

The average monthly strontium–90 concentrations in pasteurized milk from selected cities in the sampling program are presented in figure 3. Each graph shows the strontium–90 concentrations in milk from one city in each of the four U.S. Bureau of Census regions. This

[2] The conversion factor is 1.18×10^{-3} g K/pc K^{40}.

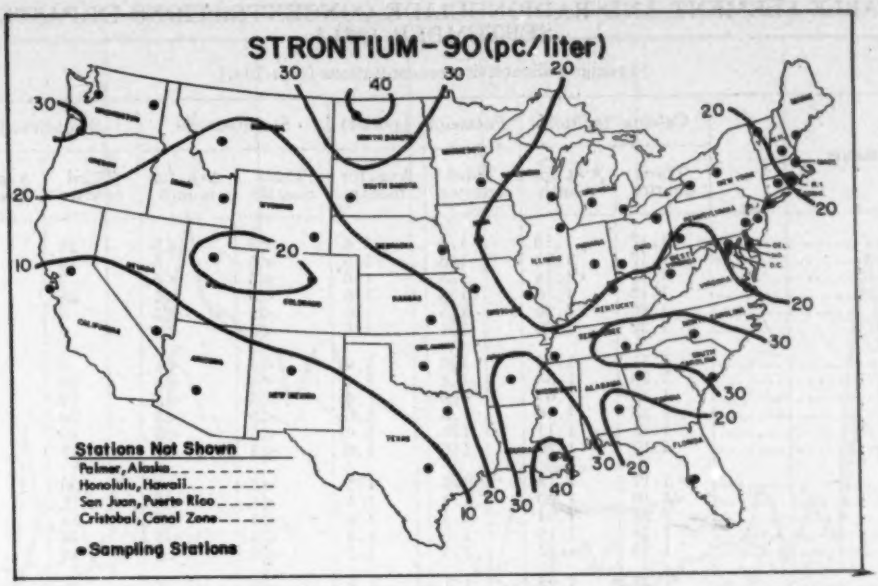

FIGURE 1.—STRONTIUM-90 CONCENTRATIONS IN PASTEURIZED MILK, SEPTEMBER, 1964

method of selection permits graphic presentation of data for each city in the network three times a year. A tabulation of the network monthly maximum, minimum, and average radionuclide concentrations in milk was given for March 1960–March 1964 in the July 1964 *RHD* (*2*).

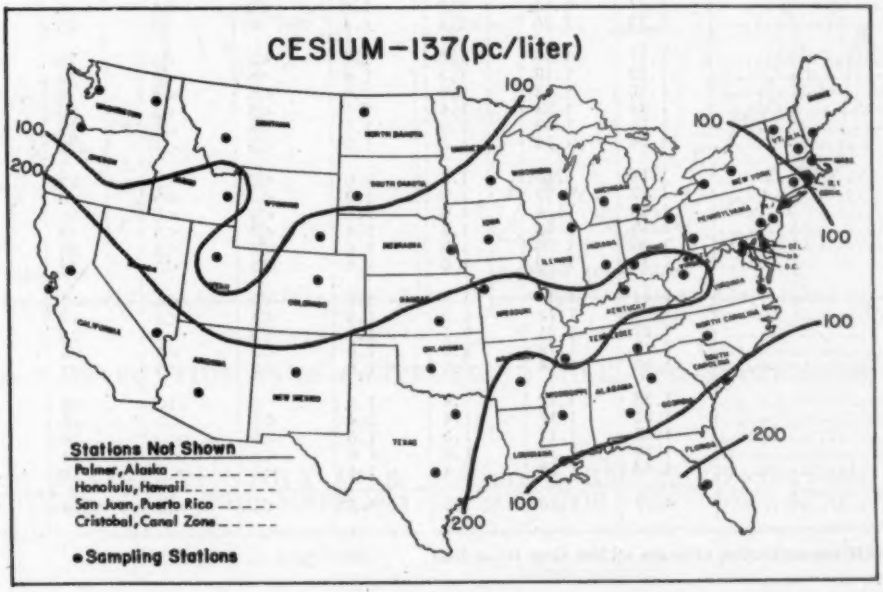

FIGURE 2.—CESIUM-137 CONCENTRATIONS IN PASTEURIZED MILK, SEPTEMBER 1964

TABLE 2.—STABLE ELEMENT AND RADIONUCLIDE CONCENTRATIONS IN PASTEURIZED MILK, SEPTEMBER 1964 [1]

[Average radioactivity concentrations in pc/liter]

Sampling locations		Calcium (g/liter)		Potassium (g/liter)		Strontium-89		Strontium-90		Cesium-137	
		Third quarter	Avg. for month	Third quarter	Avg. for month	Third quarter	Avg. for month	Third quarter	Avg. for month	Third quarter	Avg. for month
Ala:	Montgomery	1.17	1.16	1.5	1.6	<5	<5	21	19	65	60
Alaska:	Palmer	1.17	1.18	1.5	1.5	<5	5	16	16	105	100
Ariz:	Phoenix	1.15	1.14	1.5	1.6	<5	<5	3	3	25	30
Ark:	Little Rock	1.15	1.16	1.6	1.6	<5	<5	38	34	80	65
Calif:	Sacramento	1.26	1.26	1.5	1.6	<5	<5	6	7	30	30
	San Francisco	1.22	1.28	1.4	1.5	<5	<5	7	4	35	30
C. Z:	Cristobal	1.11	1.12	1.6	1.6	<5	<5	5	6	50	50
Colo:	Denver	1.25	1.30	1.4	1.4	<5	<5	20	20	100	85
Conn:	Hartford	1.10	1.07	1.6	1.6	<5	<5	19	16	110	90
Del:	Wilmington	1.15	1.16	1.5	1.5	<5	<5	20	18	85	65
D. C:	Washington	1.11	1.11	1.6	1.6	<5	<5	19	16	65	55
Fla:	Tampa	1.19	1.20	1.6	1.6	<5	<5	17	18	255	245
Ga:	Atlanta	1.17	1.18	1.5	1.5	<5	<5	28	26	105	90
Hawaii:	Honolulu	1.19	1.20	1.4	1.4	<5	<5	11	8	70	70
Idaho:	Idaho Falls	1.24	1.24	1.4	1.4	<5	<5	25	18	110	85
Ill:	Chicago	1.14	1.15	1.5	1.5	<5	<5	19	14	85	70
Ind:	Indianapolis	1.15	1.12	1.5	1.5	<5	<5	18	15	70	55
Iowa:	Des Moines	1.21	1.20	1.3	1.3	<5	5	22	20	70	65
Kans:	Wichita	1.17	1.18	1.4	1.4	<5	<5	18	17	50	40
Ky:	Louisville	1.13	1.16	1.6	1.6	<5	<5	27	23	50	40
La:	New Orleans	1.19	1.20	1.6	1.5	<5	<5	48	43	115	100
Maine:	Portland	1.14	1.08	1.5	1.5	<5	<5	29	25	175	150
Md:	Baltimore	1.13	1.14	1.5	1.5	<5	<5	21	18	70	55
Mass:	Boston	1.13	1.09	1.5	1.5	<5	<5	31	22	180	140
Mich:	Detroit	1.14	1.16	1.5	1.6	<5	<5	16	13	90	70
	Grand Rapids	1.15	1.11	1.5	1.5	<5	<5	19	15	100	35
Minn:	Minneapolis	1.21	1.22	1.5	1.5	<5	<5	27	22	110	90
Miss:	Jackson	1.21	1.21	1.5	1.5	<5	<5	37	33	85	80
Mo:	Kansas City	1.19	1.20	1.3	1.3	<5	5	26	22	55	50
	St. Louis	1.20	1.19	1.4	1.5	<5	<5	21	16	55	40
Mont:	Helena	1.20	1.19	1.5	1.5	<5	<5	20	15	115	110
Nebr:	Omaha	1.21	1.18	1.4	1.2	<5	<5	24	21	70	60
Nev:	Las Vegas	1.19	1.20	1.4	1.3	<5	<5	6	4	50	45
N. H:	Manchester	1.17	1.18	1.5	1.5	<5	<5	30	26	205	160
N. J:	Trenton	1.12	1.14	1.5	1.5	<5	<5	18	16	85	65
N. Mex:	Albuquerque	1.19	1.20	1.4	1.4	<5	<5	9	8	45	35
N. Y:	Buffalo	1.09	1.10	1.5	1.5	<5	<5	18	15	105	85
	New York	1.09	1.03	1.6	1.6	<5	<5	25	19	120	90
	Syracuse	1.12	1.12	1.5	1.5	<5	<5	15	15	80	80
N. C:	Charlotte	1.17	1.18	1.5	1.5	<5	<5	38	36	100	80
N. Dak:	Minot	1.22	1.26	1.4	1.4	10	10	49	40	145	120
Ohio:	Cincinnati	1.17	1.18	1.6	1.6	<5	<5	19	18	60	45
	Cleveland	1.12	1.13	1.5	1.6	<5	<5	19	16	90	70
Okla:	Oklahoma City	1.12	1.12	1.6	1.6	<5	<5	19	18	50	45
Ore:	Portland	1.24	1.24	1.4	1.4	<5	<5	30	30	165	120
Pa:	Philadelphia	1.11	1.09	1.5	1.5	<5	<5	18	16	80	65
	Pittsburgh	1.14	1.16	1.5	1.6	<5	<5	29	24	120	90
P. R:	San Juan	1.15	1.16	1.6	1.6	<5	<5	12	12	70	65
R. I:	Providence	1.13	1.12	1.5	1.5	<5	<5	23	22	140	115
S. C:	Charleston	1.15	1.14	1.6	1.5	<5	<5	31	31	110	110
S. Dak:	Rapid City	1.19	1.08	1.4	1.4	<5	<5	43	27	125	110
Tenn:	Chattanooga	1.20	1.20	1.6	1.6	<5	<5	39	36	90	75
	Memphis	1.16	1.16	1.6	1.6	<5	<5	28	22	55	45
Tex:	Austin	1.11	1.10	1.5	1.5	<5	<5	7	6	35	45
	Dallas	1.14	1.12	1.6	1.6	<5	<5	17	16	45	40
Utah:	Salt Lake City	1.27	1.21	1.5	1.4	<5	5	25	24	165	140
Vt:	Burlington	1.13	1.18	1.5	1.6	<5	<5	25	20	140	120
Va:	Norfolk	1.13	1.14	1.6	1.6	<5	<5	23	20	75	70
Wash:	Seattle	1.23	1.22	1.4	1.4	5	10	28	22	170	125
	Spokane	1.22	1.17	1.4	1.4	<5	<5	26	24	130	115
W. Va:	Charleston	1.13	1.11	1.5	1.5	<5	<5	24	21	50	35
Wis:	Milwaukee	1.19	1.20	1.6	1.6	<5	<5	14	12	95	80
Wyo:	Laramie	1.18	1.18	1.4	1.4	<5	<5	20	14	105	80
Network average		1.17	1.16	1.5	1.5	<5	<5	22.3	19.3	94	80

[1] Iodine-131 and barium-140 concentration averages all less than 10 pc/liter.

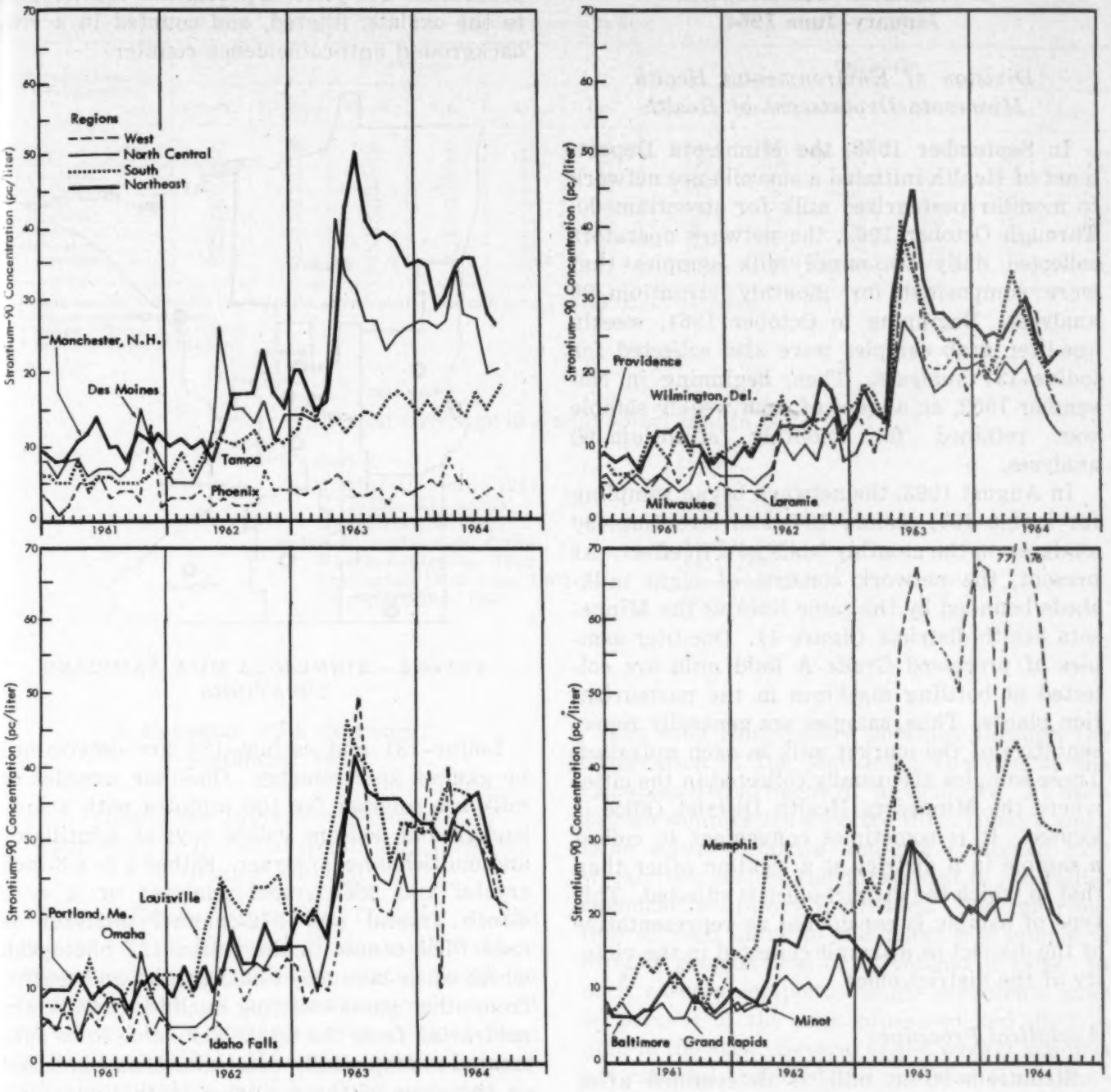

FIGURE 3.—STRONTIUM-90 IN PASTEURIZED MILK, 1961–SEPTEMBER 1964

TABLE 3.—RANGES OF STATION MONTHLY AVERAGES, FOR STRONTIUM-90, APRIL–SEPTEMBER 1964

Range (pc/liter)	Number of stations in range, 1964					
	Apr.	May	June	July	Aug.	Sept.
Under 10	4	3	4	6	7	8
10–19	12	8	6	6	23	27
20–29	28	20	23	29	23	20
30–39	12	20	17	14	6	6
40–49	2	6	10	4	4	2
50–59	2	4	2	1	0	0
60–69	3	1	0	2	0	0
70–79	0	1	1	0	0	0

TABLE 4.—RANGES OF STATION MONTHLY AVERAGES FOR CESIUM-137, APRIL–SEPTEMBER 1964

Range (pc/liter)	Number of stations in range, 1964					
	Apr.	May	June	July	Aug.	Sept.
Under 50	2	2	1	4	6	14
50–99	12	16	19	24	30	33
100–149	23	17	24	21	19	13
150–199	17	23	13	8	6	2
200–249	7	3	4	3	1	1
250–299	2	2	2	2	1	0

2. Minnesota Milk Network, January–June 1964

Division of Environmental Health
Minnesota Department of Health

In September 1958, the Minnesota Department of Health initiated a surveillance network to monitor pasteurized milk for strontium–90. Through October 1962, the network operators collected daily two-ounce milk samples that were composited for monthly strontium–90 analyses. Beginning in October 1961, weekly one-liter grab samples were also collected for iodine–131 analyses. Then, beginning in November 1962, an aliquot of each weekly sample was retained for monthly strontium–90 analyses.

In August 1963, the network began sampling for iodine–131, cesium–137, and strontium–90 analyses on the monthly basis now in effect. At present, the network consists of eight milksheds bounded by the same lines as the Minnesota health districts (figure 4). One-liter samples of processed Grade A fluid milk are collected at bottling machines in the pasteurization plants. Thus, samples are generally representative of the market milk in each milkshed. These samples are usually collected in the cities where the Minnesota Health District Office is located. It is sometimes convenient to collect a sample in a district at a location other than that in which the district office is situated. This type of sample is considered as representative of the district as a sample collected in the vicinity of the district office.

Analytical Procedure

Strontium–90 in milk is determined after ashing (450° C.) the evaporated residue from an 800-ml sample. Evaporation is accomplished by means of a steam bath and infrared overhead heating. Calcium and strontium are precipitated as oxalates at a pH of 4 from a nitric acid solution of the ash. The separated oxalates are then decomposed with nitric acid and peroxide, and the resulting solution scavenged with yttrium and barium (as chromate in the presence of ammonium chloride). Yttrium–90 is allowed to ingrow in the presence of stable yttrium carrier and then precipitated under the same conditions prevailing in the scavenging procedure. The yttrium precipitate is converted to the oxalate, filtered, and counted in a low-background anti-coincidence counter.

FIGURE 4.—MINNESOTA MILK SAMPLING LOCATIONS

Iodine–131 and cesium–137 are determined by gamma spectrometry. One-liter samples of milk are counted for 100 minutes with a low-background sodium iodide crystal scintillator and multichannel analyzer. Either a 3- x 3-inch crystal and 256-channel analyzer or a 4- x 4-inch crystal and 512-channel analyzer is used. The counts in the iodine–131 photopeak which occur because of background and scatter from other gama-emitting nuclides in milk are subtracted from the total. The value to be subtracted is empirically determined, and is based on the slope of the spectrum in this area and the magnitude of the counts in the channels adjacent to the photopeak. The minimum detectable concentration of iodine–131 in milk is 10 pc/liter.

Results

The monthly strontium–90, iodine–131, and cesium–137 concentrations in milk are given in table 5. These data as well as analytical procedures are presented in the semiannual report of the Minnesota Department of Health and Rural Cooperative Power Association (*3*).

TABLE 5.—RADIONUCLIDES IN MINNESOTA MILK, JANUARY–JUNE 1964 [a]

[Concentrations in pc/liter]

Sampling location (District office)	Strontium-90						Cesium-137					
	January	February	March	April	May	June	January	February	March	April	May	June
Bemidji	42	42	38	43	44	37	270	300	260	300	280	200
Duluth	40	41	42	43	37	60	340	340	340	330	170	320
Fergus Falls	38	19	29	37	30	32	250	270	270	290	270	180
Little Falls	[b] 45	[c] 35	[c] 27	[c] 33	[d] 31	35	[b] 310	[c] 260	[c] 210	[c] 290	[d] 270	[c] 250
Mankato	19	20	22	18	21	20	160	130	190	200	220	160
Minneapolis	30	31	32	33	33	48	290	280	220	280	270	200
Rochester	24	29	22	34	24	28	210	220	220	210	190	150
Worthington	23	12	24	27	26	23	150	170	170	190	165	140
Averages	32.6	28.6	29.5	33.5	30.8	35.4	248	246	235	261	229	200

[a] Each monthly iodine-131 concentration at each station was <10 pc/liter during January–June 1964.
[b] Sample collected at Pierz.
[c] Sample collected at St. Cloud.
[d] Sample collected at Brainerd.

Recent coverage in *Radiological Health Data:*

Period	Issue
October–December 1961 (Iodine–131 data)	*March 1962*
May–December 1961 (Strontium–90 data)	*August 1962*
March–September 1962	*April 1963*
September 1962–June 1963	*November 1963*
July–December 1963	*June 1964*

3. Canadian Milk Network,[3] September 1964

Radiation Protection Division
Department of National Health and Welfare,
Ottawa, Canada

The Radiation Protection Division of the Department of National Health and Welfare began monitoring milk for strontium–90 in November 1955. At first analyses were carried out on samples of powdered milk obtained from processing plants. However, since January 1963, liquid whole milk has been analyzed instead. With this change, more representative samples of milk consumed can be obtained, and in addition it is possible to choose milk sampling locations (see figure 5) in the same areas as the air and precipitation stations. At present, the analyses include determinations of iodine–131, strontium–89, cesium–137, and strontium–90 as well as stable potassium and calcium.

The milk samples are obtained through the cooperation of the Marketing Division of the Canadian Department of Agriculture. At each station samples are collected three times a week from selected dairies and are combined into weekly composites and forwarded to the radiochemical laboratory in Ottawa. The contribution of each dairy to the composite sample is directly proportional to its volume of sales. In most cases a complete sample represents over 80 percent of the milk processed and distributed in the area. Several of the weekly samples are randomly selected and analyzed for iodine–131. The results of the spot checks for iodine–131 will not be reported unless there is evidence that the levels are rising. A monthly composite of the samples is analyzed for strontium–90, cesium–137, and stable potassium and calcium.

Analytical Methods

Radiochemical methods are used for the analysis of iodine–131 (*4*). For the analysis of radiostrontium, carrier strontium is added to a one-liter sample of milk, and the milk is then placed in a tray lined with a polyethylene sheet

[3] Data from *Radiation Protection Programs, Vol. 2, No. 10*, 25–29, Radiation Protection Division, Canadian Department of National Health and Welfare (October 1964).

FIGURE 5.—CANADIAN MILK SAMPLING STATIONS

and evaporated under infra-red lamps. The residue is ashed in a muffle furnace at 450° C., dissolved in dilute nitric acid, and strontium separated by fuming nitric acid precipitation. The combined strontium–89 and strontium–90 are determined by counting in a low background beta counter. Strontium–90 is determined separately by extracting and counting the yttrium–90 daughter, while strontium–89 is estimated by difference from the total radiostrontium measurement. Appropriate corrections are made for self-absorption and counter efficiency at all stages. Calcium is determined by flame photometry.

Cesium–137 is determined by gamma spectroscopy using a scintillation crystal and a multichannel pulse height analyzer. A sample consisting of 4.5 liters of milk is placed in a sample tray constructed in the form of an inverted well to accommodate the 5 x 4-inch sodium iodide crystal detector. The sample is counted for 100 minutes and the gamma spectrum recorded. Estimates are made of the potassium–40 and cesium–137 content of the milk by comparison of the spectrum with the spectra of standard preparations of these two radionuclides. With this method the potassium–40 concentration is determined and the Compton contribution of this radionuclide to the cesium–137 photopeak is subtracted to obtain the cesium–137 concentration. The stable potassium content is estimated from the potassium–40 concentration.

Sources of Error

In the iodine and strontium determinations, tests indicate that the statistical error (95 percent confidence level) in the chemical operations involved is about plus-or-minus 10 percent. This value is independent of the concentration of the radioisotope in the milk because it depends only on the recovery of the carrier. In the determination of cesium–137 this factor is not involved.

The chemical procedures error must be combined with the counting error which depends primarily on the concentration of the nuclide in the sample, the background radiation, and the length of time the sample and background are counted. This counting error has been evaluated mathematically for the particular counting arrangement used.

The overall errors, estimated on the basis indicated above, are given in table 6.

TABLE 6.—TOTAL ERROR FOR VARIOUS RADIONUCLIDE CONCENTRATIONS IN MILK [a]

Nuclide	Error for 10 pc/liter	Error for 50 pc/liter	Error for 100 pc/liter
Strontium-89	±25%	±20%	±15%
Strontium-90	±15%	±10%	±10%
Iodine-131	±50%	±20%	±10%
Cesium-137	±60%	±25%	±10%

[a] All errors are 2σ values, representing 95 percent confidence levels.

Results

Table 7 presents monthly averages of strontium–90, cesium–137, and stable calcium and potassium in Canadian whole milk. Spot checks for iodine–131 and strontium–89 indicate that all samples had <5 pc/liter.

TABLE 7.—RADIONUCLIDES IN CANADIAN WHOLE MILK, SEPTEMBER 1964

[Radionuclide concentration in pc/liter]

Station	Calcium (g/liter)	Potassium (g/liter)	Strontium-90	Cesium-137
Calgary	1.19	1.5	26.4	116
Edmonton	1.15	1.6	30.6	112
Ft. William	1.13	1.6	38.1	193
Fredericton	1.18	1.6	39.0	180
Halifax	1.18	1.6	36.3	159
Montreal	1.13	1.6	25.6	104
Ottawa	1.13	1.6	17.8	98
Quebec	1.13	1.6	35.0	164
Regina	1.13	1.6	30.7	109
St. John's, Nfld	1.11	1.6	61.6	248
Saskatoon	1.17	1.6	37.3	114
Sault Ste. Marie	1.13	1.6	33.7	168
Toronto	1.13	1.6	11.2	71
Vancouver	1.20	1.6	40.5	285
Windsor	1.13	1.6	11.2	54
Winnipeg	1.15	1.6	33.8	180
Average	1.15	1.6	31.8	147

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APPLICATION OF RADIONUCLIDE CONCENTRATIONS IN MILK TO DOSE ASSESSMENT, OCTOBER 1963—SEPTEMBER 1964

Division of Radiological Health, Public Health Service

The concentration of specific radionuclides in milk analyzed as part of the pasteurized Milk Network (PMN) is reported on a monthly basis in *RHD*. In terms of radiological health surveillance activities, an important aspect of these data is the estimation of resultant radiation dose to population groups.

Approximate relationships between certain radionuclide intakes and dose have been applied to the formulation of daily intake guides (*1*) and permissible concentrations in selected environmental media (*2*). Although these guides are not themselves directly applicable to worldwide fallout, a comparison with environmental contamination levels does yield a measure of population dosage. In general, intake-dose and dose-biological effect relationships used in formulating the guides cited are based on continuous intake over an entire lifetime. However, for general surveillance purposes, yearly average intakes used with discretion may be compared directly with the levels adopted as lifetime intake guides. Thus, the radionuclide concentrations in milk, averaged over a year's time, together with milk consumption data, might be used in conjunction with the references cited above to approximate the radiation dose to a specific population group from a specific radionuclide. Table 1 presents annual averages of radionuclide concentrations in milk sampled by the PMN. Limited data are available for estimating the average daily milk consumption (on a volume basis) for specific age groups in the U. S. population (*3,4*).

Total dietary intake is of prime interest, and since the intake via consumption of milk constitutes only a portion of the total radionuclide intake, the relationship of milk intake to total dietary intake is of importance in evaluating milk surveillance data. The Federal Radiation Council (*5*) notes: "A number of studies have shown that conservative estimates of the strontium–90 to calcium ratio in the total diet may be made by multiplying the ratio of strontium–90 to calcium in milk in a particular locality by 1.5."[1] Thus, a rough index of the total dietary intake of strontium–90 on an annual basis may be made from PMN annual averages by using this factor and the assumptions of approximately 1.2 g of calcium per liter in PMN samples and a 1.0 g daily intake of calcium.

In the case of iodine–131, milk can be considered the major source because of the rapid distribution and consumption of fresh milk. With most other foods, normal processing and distribution, allows time for the radioactive decay of this short-lived nuclide to insignificant levels.

The situation with respect to strontium–89 is more complicated. Its halflife of some 50 days makes it difficult to estimate the relative contribution made by sources other than milk to the total dietary intake.

[1] This ratio may vary from 1 to 2, depending on changes in rate of fallout deposition and relative consumption of non-milk products whose contamination reflects temporal and local deposition patterns (*6*).

TABLE 1.—MOVING ANNUAL AVERAGE RADIONUCLIDE CONCENTRATIONS IN MILK[a,b]

[Concentrations in pc/liter]

Sampling locations		Strontium-89		Strontium-90		Cesium-137	
		Sept 1963–Aug 1964	Oct 1963–Sept 1964	Sept 1963–Aug 1964	Oct 1963–Sept 1964	Sept 1963–Aug 1964	Oct 1963–Sept 1964
Ala:	Montgomery	5	3	23	23	87	86
Alaska:	Palmer	12	9	25	24	154	149
Ariz:	Phoenix	3	3	4	4	26	26
Ark:	Little Rock	9	5	45	45	141	134
Calif:	Sacramento	3	3	9	9	53	51
	San Francisco	5	4	10	10	60	58
C. Z.	Cristobal	[d]	3	[d]	5	[d]	48
Colo:	Denver	8	6	19	19	93	92
Conn:	Hartford	6	4	23	22	162	156
Del:	Wilmington	5	3	25	24	134	128
D. C:	Washington	6	4	20	19	90	88
Fla:	Tampa	4	3	15	16	245	241
Ga:	Atlanta	8	5	32	32	142	139
Hawaii:	Honolulu	4	4	11	11	82	80
Idaho:	Idaho Falls	14	13	28	28	179	177
Ill:	Chicago	5	4	20	20	121	118
Ind:	Indianapolis	5	4	22	22	102	100
Iowa:	Des Moines	10	8	26	26	96	95
Kans:	Wichita	7	6	21	21	71	68
Ky:	Louisville	10	6	32	32	97	94
La:	New Orleans	9	5	51	51	152	149
Maine:	Portland	8	5	33	32	219	210
Md:	Baltimore	7	5	23	22	107	103
Mass:	Boston	9	5	36	34	247	235
Mich:	Detroit	5	3	20	19	121	117
	Grand Rapids	5	4	22	21	132	127
Minn:	Minneapolis	14	11	34	33	158	154
Miss:	Jackson	9	6	42	42	112	110
Mo:	Kansas City	12	8	29	29	86	85
	St. Louis	9	7	24	23	87	85
Mont:	Helena	10	7	29	28	190	184
Nebr:	Omaha	11	9	27	27	101	99
Nev:	Las Vegas	7	6	11	10	81	78
N. H:	Manchester	8	5	34	33	259	247
N. J:	Trenton	6	4	20	19	123	118
N. Mex:	Albuquerque	4	3	12	11	56	55
N. Y:	Buffalo	6	4	22	21	152	146
	New York	8	5	29	27	176	166
	Syracuse[c]	7	4	22	21	152	145
N. C:	Charlotte	8	5	36	36	119	115
N. Dak:	Minot	16	9	60	58	159	156
Ohio:	Cincinnati	5	4	24	24	96	94
	Cleveland	5	3	22	22	118	115
Okla:	Oklahoma City	6	4	23	23	74	72
Ore:	Portland	12	10	32	32	177	172
Pa:	Philadelphia	4	3	21	21	125	123
	Pittsburgh	6	4	31	30	159	153
P. R:	San Juan	4	3	13	13	74	74
R. I:	Providence	5	3	26	25	175	170
S. C:	Charleston	7	5	31	32	132	130
S. Dak:	Rapid City	15	11	45	43	159	156
Tenn:	Chattanooga	10	6	41	41	128	125
	Memphis	7	5	33	32	77	76
Tex:	Austin	3	3	9	9	44	42
	Dallas	4	3	20	20	70	69
Utah:	Salt Lake City	11	9	27	27	187	185
Vt:	Burlington	7	5	28	27	195	187
Va:	Norfolk	5	4	23	18	98	96
Wash:	Seattle	12	9	29	28	165	159
	Spokane	12	10	30	30	150	148
W. Va:	Charleston	8	5	28	28	89	85
Wis:	Milwaukee	4	3	19	18	136	133
Wyo:	Laramie	11	10	22	22	116	112
Network average		8	5	25.9	25.0	127	122

[a] Annual averages were computed on the basis of 52 weekly averages except as noted.
[b] Annual averages for iodine-131 and barium-140 at each station were <10.
[c] Annual average was computed on the basis of 48 weekly averages. No sample was collected during July 1964.
[d] Annual average not shown for Canal Zone. Station was included in PMN in Oct. 1963.

The relative contribution of milk to the total dietary intake of cesium–137 is not well defined and depends principally on the amount of freshly deposited cesium–137 on products used for human and animal consumption, and the progress of cesium–137 through the food chain.

The data in table 1 are calculated as follows: results from all samples collected in each week (Sunday through Saturday) are averaged, and the averages for all weeks terminating in each of twelve consecutive months are averaged to obtain the annual average.[2] To obtain the annual average daily intake (pc/day) of radionuclides from milk, the annual average concentration values (pc/liter) in table 1 must be multiplied by the annual average daily consumption (liters/day) of milk.

Monthly variations of radionuclide concentrations in milk are influenced by a number of combined causes such as meteorologic conditions and dairying practices. The moving yearly average (table 1), obtained by updating the previous twelve-month average by one month, shows variations averaged over the year and tends to minimize purely seasonal variations. This method, therefore, shows trends over considerable periods of time.

[2] Beginning with the October 1963 data, iodine–131 values of <10 pc/liter are considered to be zero for averaging purposes; previously, 5 pc/liter was used for calculating the averages.

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CESIUM-137 IN MILK FROM DRY-LOT AND PASTURE-FED COWS IN FORT COLLINS, COLORADO, DURING 1963 [1]

James E. Johnson and *Gerald M. Ward*[2]

Determinations of Cs^{137} in milk were begun at Colorado State University (C.S.U.) in 1962 as part of a controlled study of the passage of this nuclide through the food chain. All milk samples were collected from cows in the C.S.U. herd. Eleven high-producing Holstein cows were put on pasture May 1, 1963, and taken off September 9, 1963, and are referred to as the "pasture herd." These cows were fed some hay and grain in addition to pasture. Milk samples were collected and composited from this herd every two days during the pasture season. The control group was the remainder of the C.S.U. herd, consisting of about 80 cows of the Holstein, Jersey, Guernsey, and Brown Swiss breeds, which were fed throughout the year in the dry lot. Representative milk samples were collected from this group every two days from May 1 to September 9, 1963, and weekly during the remainder of the year, and are referred to as "bulk milk" samples.

The pasture area consisted of ten acres of irrigated brome grass and alfalfa divided into three sections for rotational grazing. The pasture was flood irrigated four times during the summer.

Milk samples were analyzed for Cs^{137}, I^{131}, and K^{40} in a 5.47-liter Marinelli-type beaker using a 4″ by 8″ NaI (T1) crystal connected to a 400-channel, pulse height analyzer. The system was calibrated by counting known activities of the three nuclides in the same geometry for determination of a "spectrum stripping" equation.

Figure 1 shows the Cs^{137} levels in milk from the dry-lot herd (bulk milk) and the pasture herd for 1963. Also shown are the levels from a group of the highest milk-producing cows in the herd, milked three times daily (3x), and fed in the dry lot. Superimposed on the graph is the Cs^{137} deposition from precipitation on the pasture expressed in $\mu c/mile^2$ by the vertical bars (scale on right).

The milk from the pasture herd was sampled before the cows were put on pasture, and it was confirmed that the Cs^{137} activity averaged the same as the dry-lot herd. When the pasture herd was put on pasture, the milk levels immediately increased. After seven days, the herd was removed for one day for irrigation of the pasture. The herd was returned to the pasture, and the milk levels decreased with a 5-day half-time attributable to washing of the forage by the irrigation water and/or dilution of the activity present by new pasture growth. The levels increased due to substantial rain on day 137 (May 14) and, in general, the pasture milk levels closely reflected the Cs^{137} deposition by rainfall. During a dry period from day 169 to day 191, milk levels decreased with a 15.4-day half-time with, again, immediate response to subsequent rains.

The bulk milk remained relatively constant during the winter and spring months, during which time the cows were fed the same feed. On June 13 (day 164), when the cows in the dry lot started receiving a small amount (20 lbs. per day) of green-cut alfalfa, their Cs^{137} milk levels (bulk milk) increased. Later, on day 220, first-cutting 1963 hay replaced 1962

[1] This work was supported by A.E.C. Contract AT(11–1)–1171 with the U.S. Atomic Energy Commission.

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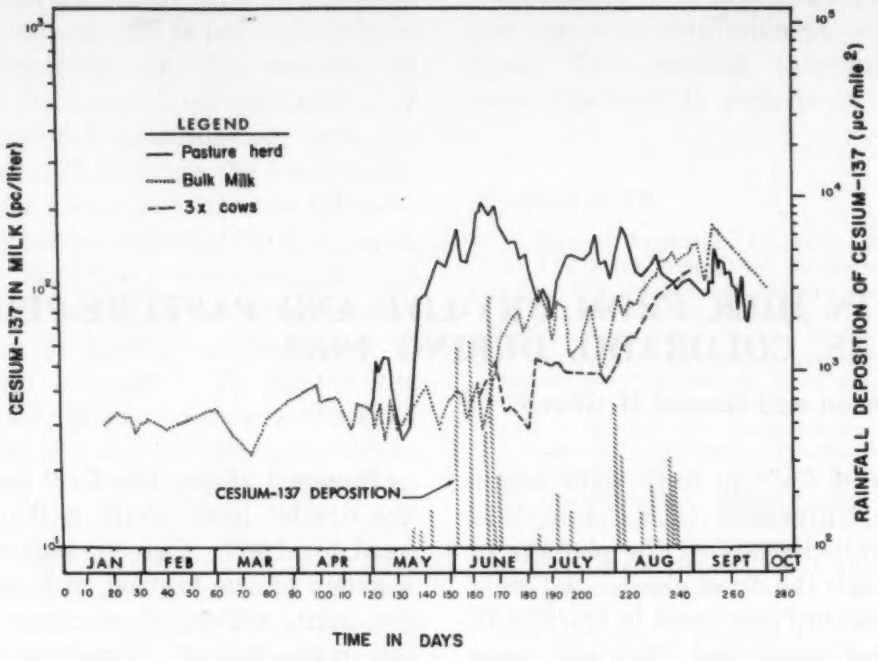

FIGURE 1.—CESIUM-137 CONCENTRATIONS IN MILK FOR PASTURE AND DRY-LOT FED COWS; AND RAINFALL CESIUM-137 DEPOSITION IN 1963

hay, and another increase occurred. The small-scale fluctuations in milk levels can be explained almost exactly by day-to-day differences in the activity of the green-cut alfalfa. The increase in milk activity of the 3x group, starting on day 220, is also explained by a change from third-cutting hay harvested in August 1962 to first-cutting hay harvested in June 1963.

Later in the summer, it is interesting to note that, as the milk from the pasture herd was decreasing in Cs^{137} activity, the levels of milk from the dry-lot herd (bulk milk) exceeded the pasture herd levels. This was probably due to the fact that the first-cutting hay being fed to the dry-lot cows had higher concentrations of Cs^{137} than the pasture forage. On day 251, September 9, the "pasture herd" was taken off pasture and fed the same hay as the dry-lot herd. This produced an immediate increase in the Cs^{137} concentration in the milk of the pasture herd. The cows were then changed to a diet containing only five pounds of hay and 25–40 pounds of grain, which resulted in an abrupt decline. Even though the Cs^{137} in grains is probably more available to the cow than that in hay, the activity per unit weight was much lower and the milk levels decreased with a half-time of 37 days.

Hay and forage samples presently are being analyzed for Cs^{137} to determine the percentage appearing in the milk as influenced by pasture and dry-lot feeding practices.

Conclusions

The data show that milk levels responded rapidly to changes in the activity of the cows' feed and that the activity of pasture forage reached a maximum coincident with heavy spring rains and declined thereafter. The data also illustrate the situation which commonly occurs under farm conditions with cows on pasture. Poor pastures in late summer require the feeding of more hay, which is usually first cutting (late spring harvest) and which will have a much greater Cs^{137} contamination (as well as, presumably, Sr^{90}) than will late summer pasture. Similarly, dry-lot fed cows in late summer or early fall are likely to have greater Cs^{137} levels in their milk than cows which are primarily dependent on pasture because dry-lot fed cows will usually be receiving first cutting hay at this time. This, of course, would not necessarily be true in periods of continued nuclear testing.

RADIONUCLIDES IN INSTITUTIONAL DIET SAMPLES, APRIL-JUNE, 1964

Division of Radiological Health, Public Health Service

The determination of radionuclide concentrations in the diet constitutes an important element of an integrated program of environmental radiation surveillance and assessment. In recognition of the potential significance of the diet in contributing to total environmental radiation exposures, the Public Health Service initiated its Institutional Diet Sampling Program in 1961. This program is administered by the Division of Radiological Health with the assistance of the Division of Environmental Engineering and Food Protection (*1*).

FIGURE 1.—INSTITUTIONAL DIET SAMPLING LOCATIONS

The program is designed to estimate the dietary intake of radionuclides in a selected population group ranging from children to young adults of school age. Initially, the program consisted of sampling diets in eight institutions, but it has since been expanded to 41 boarding schools or institutions, geographically distributed as shown in figure 1. Institutions selected range from financially well-to-do boarding schools to orphanages with severe economic limitations. Each institution (sampling point) except the one at Los Angeles is located in a community from which the PHS Pasteurized Milk Network collects samples. The analytical data from this program supplement the findings for the Institutional Diet Sampling Program.

Sampling Procedure

In general, the sampling procedure is the same at each institution. Each sample represents the edible portion of the diet for a full 7-day week (21 meals plus soft drinks, candy bars, or other in-between snacks) obtained by duplicating the meals of a different individual each day. Each institution supplies one complete 7-day, 21-meal diet sample each month. Each day's sample is kept frozen during the collection period. After collection, the total sample is packed in dry ice and shipped by air express to either the Southwestern Radiological Health Laboratory, Las Vegas, Nevada, the Southeastern Radiological Health Laboratory, Montgomery, Alabama, or the Northeastern Radiological Health Laboratory, Winchester, Massachusetts.

The sample for each day is packaged in three parts: (1) solid food and semi-solid foods minus those portions that would not ordinarily be eaten; (2) liquid milk; (3) other beverages such as soft drinks, coffee, and tea. Drinking water is not included in these samples nor reported in this report. A record of the contents of each meal and the approximate amount of each item is made at the institution and sent with the sample.

Analytical Procedures

Because calcium compounds may have an effect on the uptake of important bone-seeking radionuclides such as strontium–89 and strontium–90 (*2*), they are included in the analytical program. Total weight is accurately determined in the laboratory. Stable calcium and stable potassium determinations are obtained by conventional gravimetric or spectrophotometric methods. Samples usually range from 6 to 16 liters in volume and weigh from 8 to 20 kilograms.

The radioanalysis program is designed around three basic procedures: (1) gamma spectroscopy; (2) chemical separation of strontium–89 and strontium–90 with subsequent counting; and (3) radium–226 analysis. In the absence of interferences other than that from naturally-occurring radioactive potassium (K^{40}), minimum detectable concentrations for the gamma scan for iodine–131, cesium–137, and barium–140 are 10 pc/kg. Approximate minimum detectable concentrations for strontium–89, strontium–90, and radium–226 are: 5, 1, and 1 pc/kg, respectively.

Data

Table 1 gives the results of the laboratory analyses of the food samples. In this table are presented concentrations of various radionuclides and stable elements expressed as picocuries per kilogram of diet or grams per kilogram of diet, respectively.

Table 2 presents the dietary intake data expressed on a per-day basis from April through June 1964 for the 41 institutions from which samples were received. The intake values in this table were obtained by multiplying the food consumption rate in kg/day (column 4 of table 2) times the concentration values in grams or picocuries per kilogram of diet given in table 1. Also contained in the table is the range of ages of the children from which samples are being obtained. The reported radionuclide concentrations of these samples are extrapolated to the midpoint of the sample collection period.

Certain of the radioanalyses are reported by the laboratories as being "less-than" (<) a specified value. For data computations, the method employed is to use a zero for <10 pc/kg values for iodine–131 and barium–140. A 2.5 pc/kg was substituted for <5 pc/kg of strontium–89.

Previous coverage in *Radiological Health Data:*

Period	Issue
July–September 1962	*April 1963*
October–December 1963	*July 1963*
January–March 1963	*September 1963*
April–June 1963	*December 1963*
July–September 1963	*March 1964*
October–December 1963	*July 1964*
January–March 1964	*October 1964*

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TABLE 1.—INSTITUTIONAL DAILY DIETARY INTAKE (BASED ON A COMPOSITE 7 CONSECUTIVE DAY SAMPLE IN EACH MONTH), SECOND QUARTER 1964

Location of institution	1964	Total weight (kg/day)	Calcium (grams per kg.)	Potassium (grams per kg.)	Radium-226 [a b] (picocuries per kg.)	Strontium-89 [b] (picocuries per kg.)	Strontium-90 (picocuries per kg.)	Cesium-137 (picocuries per kg.)	Barium-140 [b] (picocuries per kg.)	Iodine-131 [b] (picocuries per kg.)
Ala., Montgomery	April	—	—	—	—	—	—	—	—	—
	May	—	—	—	—	—	—	—	—	—
	June	2.34	0.6	1.1	[d] NA	<5	14	50	<10	<10
Alaska, Palmer	April	1.50	0.6	1.1	0.8	<5	16	95	<10	<10
	May	1.26	0.7	1.5	0.6	5	27	95	<10	<10
	June	1.10	0.8	1.6	0.1	<5	29	155	<10	<10
Ark., Little Rock	April	2.05	0.6	1.3	*1.6	5	23	85	<10	<10
	May	1.68	0.6	1.2	*2.2	<5	39	115	<10	<10
	June	1.90	0.6	1.3	NA	<5	28	75	<10	<10
Calif., Los Angeles	April	2.01	0.8	1.5	0.5	<5	9	50	<10	10
	May	1.81	0.7	1.6	0.4	<5	7	55	<10	10
	June	1.30	0.6	1.4	0.5	<5	10	50	<10	<10
Colo., Denver	April	2.95	0.7	1.8	0.5	<5	16	80	<10	<10
	May	2.11	0.6	1.6	0.2	<5	13	60	<10	<10
	June	1.61	0.8	1.6	0.4	10	14	65	<10	<10
Del. Wilmington	April	2.11	0.7	1.6	0.6	<5	17	120	<10	<10
	May	1.93	0.8	1.5	0.3	<5	26	145	<10	<10
	June	1.93	0.9	1.6	0.8	<5	17	105	<10	<10
Fla., Tampa	April	2.29	0.5	0.9	*1.5	<5	12	100	<10	<10
	May	2.18	0.6	1.6	*3.0	<5	13	135	<10	<10
	June	2.15	0.5	1.0	NA	<5	9	130	<10	<10
Ga., Atlanta	April	—	—	—	—	—	—	—	—	—
	May	—	—	—	—	—	—	—	—	—
	June	1.68	0.6	1.3	NA	<5	21	75	<10	<10
Hawaii, Honolulu	April	1.79	0.4	1.6	1.0	<5	8	100	<10	<10
	May	• NS	NS	NS	NS	11.5	NS	NS	NS	NS
	June	1.52	0.5	1.2	0.5	10	15	65	<10	<10
Idaho, Idaho Falls	April	—	—	—	—	—	—	—	—	—
	May	1.92	0.7	1.5	1.0	<5	40	180	<10	<10
	June	1.85	0.6	2.0	0.5	<5	31	195	<10	<10
Ill., Chicago	April	1.54	0.6	1.5	0.3	<5	15	100	<10	<10
	May	1.36	0.7	1.7	0.3	<5	19	110	<10	<10
	June	1.33	0.7	1.4	0.5	<5	15	90	<10	<10
Ind., Indianapolis	April	—	—	—	—	—	—	—	—	—
	May	—	—	—	—	—	—	—	—	—
	June	1.86	0.8	1.8	0.8	<5	19	80	<10	<10
Iowa, Des Moines	April	—	—	—	—	—	—	—	—	—
	May	—	—	—	—	—	—	—	—	—
	June	2.01	0.8	1.2	NA	<5	19	65	<10	<10
Kans., Wichita	April	—	—	—	—	—	—	—	—	—
	May	—	—	—	—	—	—	—	—	—
	June	2.32	0.7	1.4	NA	<5	14	70	<10	<10
Ky., Louisville	April	—	—	—	—	—	—	—	—	—
	May	—	—	—	—	—	—	—	—	—
	June	1.56	0.7	1.1	NA	<5	23	55	<10	<10
La., New Orleans	April	2.66	1.6	1.6	*2.8	<5	34	110	<10	<10
	May	2.60	0.7	1.5	*7.9	<5	31	115	<10	<10
	June	2.60	0.6	1.2	NA	10	25	85	<10	<10
Maine, Portland	April	2.38	0.7	1.6	0.3	<5	22	140	<10	<10
	May	2.30	0.6	1.5	0.3	<5	20	130	<10	<10
	June	2.17	0.7	1.4	0.2	<5	23	125	<10	<10
Md., Baltimore	April	—	—	—	—	—	—	—	—	—
	May	—	—	—	—	—	—	—	—	—
	June	1.73	0.8	1.6	NA	<5	25	95	<10	<10
Mass., Boston	April	1.76	0.6	1.5	0.3	<5	23	165	<10	<10
	May	2.17	0.6	1.7	0.3	<5	17	150	<10	<10
	June	1.62	0.9	1.7	0.7	<5	33	200	<10	<10
Mich., Detroit	April	—	—	—	—	—	—	—	—	—
	May	—	—	—	—	—	—	—	—	—
	June	2.07	0.8	1.4	0.7	<5	17	95	<10	<10
Minn., Minneapolis	April	1.68	0.5	1.5	0.6	<5	19	100	<10	<10
	May	1.98	0.6	1.4	0.5	25	10	75	<10	<10
	June	1.81	0.5	1.4	1.3	<5	35	95	<10	<10
Miss., Columbia	April	1.90	0.9	1.3	*4.0	<5	38	230	<10	<10
	May	2.04	0.9	1.4	*2.8	5	34	190	<10	<10
	June	1.88	0.9	1.2	NA	<5	33	135	<10	<10
Mo., St. Louis	April	3.24	0.8	1.5	0.4	5	24	70	<10	<10
	May	2.32	0.7	1.5	0.6	<5	22	65	<10	<10
	June	2.42	0.7	1.2	0.4	15	24	55	<10	<10
Mont., Helena	April	2.28	0.6	1.2	0.5	10	15	95	<10	<10
	May	2.05	0.5	1.2	0.4	5	13	100	<10	<10
	June	1.93	0.5	1.3	0.5	5	15	145	<10	<10

TABLE 1.—INSTITUTIONAL DAILY DIETARY INTAKE (BASED ON A COMPOSITE 7 CONSECUTIVE DAY SAMPLE IN EACH MONTH), SECOND QUARTER 1964—Continued

Location of institution	1964	Total weight (kg/day)	Calcium (grams per kg.)	Potassium (grams per kg.)	Radium-226 [a] [b] (picocuries per kg.)	Strontium-89 [b] (picocuries per kg.)	Strontium-90 (picocuries per kg.)	Cesium-137 (picocuries per kg.)	Barium-140 [b] (picocuries per kg.)	Iodine-131 [b] (picocuries per kg.)
Nebr., Omaha	April	1.69	1.0	1.6	0.6	<5	22	100	<10	<10
	May	2.29	0.9	1.3	1.4	<5	22	125	<10	<10
	June	2.14	0.8	1.5	0.8	<5	20	60	<10	<10
N. Mex., Albuquerque	April	2.03	0.7	1.3	0.6	<5	10	35	<10	<10
	May	1.71	0.9	1.5	0.9	<5	9	40	<10	<10
	June	2.00	0.8	1.3	0.4	5	19	30	<10	<10
N. Y., New York	April	1.55	1.0	1.5	1.2	<5	15	115	<10	<10
	May	—	—	—	—	—	—	—	—	—
	June	—	—	—	—	—	—	—	—	—
N. C., Charlotte	April	—	—	—	—	—	—	—	—	—
	May	—	—	—	—	—	—	—	—	—
	June	2.26	0.7	1.3	NA	<5	27	70	<10	<10
N. D. Fargo	April	—	—	—	—	—	—	—	—	—
	May	—	—	—	—	—	—	—	—	—
	June	1.48	0.5	1.3	1.7	<5	15	130	<10	<10
Ohio, Cleveland	April	2.11	0.5	1.9	0.3	<5	13	100	<10	<10
	May	1.88	0.6	1.4	0.3	<5	13	100	<10	<10
	June	2.14	0.7	1.7	0.5	<5	17	95	<10	<10
Okla., Oklahoma City	April	—	—	—	—	—	—	—	—	—
	May	1.90	0.7	1.6	*2.2	<5	17	65	<10	<10
	June	1.67	0.6	1.0	NA	<5	15	55	<10	<10
Penn., Pittsburgh	April	2.45	0.6	1.6	0.6	<5	14	110	<10	<10
	May	2.25	0.6	1.5	0.6	<5	19	100	<10	<10
	June	2.24	0.6	1.5	1.0	<5	22	100	<10	<10
S. C., Charleston	April	—	—	—	—	—	—	—	—	—
	May	—	—	—	—	—	—	—	—	—
	June	1.27	0.5	1.5	NA	<5	16	105	<10	<10
Tenn., Memphis	April	1.42	0.7	1.4	*2.8	<5	29	60	<10	<10
	May	1.41	0.5	1.3	*2.6	<5	24	55	<10	<10
	June	1.52	0.6	1.1	NA	<5	18	50	<10	<10
Texas, Austin	April	1.74	0.5	1.1	*1.0	<5	6	30	<10	<10
	May	2.00	0.4	1.2	*1.6	5	8	50	<10	<10
	June	1.65	0.4	0.9	NA	<5	10	40	<10	<10
Utah, Salt Lake City	April	1.34	0.7	1.5	0.6	5	41	155	<10	<10
	May	1.81	0.9	1.4	0.9	10	27	125	<10	<10
	June	1.20	0.8	1.4	1.6	<5	14	90	<10	<10
Vt., Burlington	April	1.89	0.5	1.5	0.3	<5	14	115	<10	<10
	May	1.42	0.5	1.5	0.4	<5	16	125	<10	<10
	June	1.26	0.6	1.8	0.3	<5	28	140	<10	<10
Va., Norfolk	April	2.21	0.5	1.1	*2.1	<5	16	65	<10	<10
	May	2.08	0.5	1.2	*3.3	<5	15	60	<10	<10
	June	2.23	0.5	1.1	NA	<5	18	75	<10	<10
Wash., Seattle	April	1.99	0.6	1.6	0.6	15	43	90	<10	<10
	May	1.88	0.6	1.3	0.7	20	27	90	<10	<10
	June	1.72	0.8	1.1	0.4	15	25	110	<10	<10
Wis., Milwaukee	April	—	—	—	—	—	—	—	—	—
	May	1.80	0.6	1.6	0.3	<5	15	110	<10	<10
	June	1.87	0.7	1.6	0.7	<5	19	95	<10	<10
Wyo., Laramie	April	2.05	0.6	1.5	0.8	<5	15	90	<10	<10
	May	1.42	0.8	1.4	2.0	<5	18	65	<10	<10
	June	1.67	0.6	1.4	0.5	<5	32	80	<10	<10
Monthly Average	April	2.02	0.6	1.4	0.6	<5	20	100	<10	<10
	May	1.92	0.7	1.4	0.6	<5	20	100	<10	<10
	June	1.83	0.7	1.4	0.7	<5	21	90	<10	<10

[a] Asterisk (*) to the left of number indicates *total radium*.
[b] Average for radium-226; does not include total radium. For averaging purposes "0" was substituted for <10 values for I-131 and Ba-140; 2.5 was substituted for less than 5 values for Sr-89.
[c] Dash (—) indicates station not in operation.
[d] NA indicates no analysis.
[e] NS indicates no sample.

TABLE 2.—INSTITUTIONAL DAILY DIETARY INTAKE (BASED ON A COMPOSITE 7 CONSECUTIVE DAY SAMPLE IN EACH MONTH), SECOND QUARTER 1964

Location of institution	1964	Age (years)	Total weight (kg/day)	Calcium (grams per day)	Potassium (grams per day)	Radium-226 [a] (picocuries per day)	Strontium-89 (picocuries per day)	Strontium-90 (picocuries per day)	Cesium-137 (picocuries per day)	Barium-140 (picocuries per day)	Iodine-131 (picocuries per day)
Ala., Montgomery	April	12–16	[b]—	—	—	—	—	—	—	—	—
	May		—	—	—	—	—	—	—	—	—
	June		2.34	1.4	2.6	* NA	5	33	115	0	0
Alaska, Palmer	April	6–18	1.50	0.9	1.6	1	5	24	140	0	0
	May		1.26	0.9	1.9	1	5	34	120	0	0
	June		1.40	1.1	2.2	0	5	41	215	0	0
Ark., Little Rock	April	6–13	2.05	1.2	2.7	*3.2	5	46	170	0	0
	May		1.68	1.0	2.0	*3.8	5	65	195	0	0
	June		1.90	1.1	2.5	NA	5	53	140	0	0
Calif., Los Angeles	April	12–18	2.01	1.6	3.0	1	5	18	100	0	0
	May		1.81	1.3	2.9	1	5	13	100	0	0
	June		1.30	0.8	1.8	1	5	13	65	0	0
Colo., Denver	April	8–17	2.95	2.1	5.3	1	5	47	235	0	0
	May		2.11	1.3	3.4	0	5	27	125	0	0
	June		1.61	1.3	2.6	1	15	23	105	0	0
Del., Wilmington	April	7–12	2.11	1.5	3.4	1	5	35	250	0	0
	May		1.93	1.4	2.9	0	0	50	280	0	0
	June		1.93	1.7	3.1	2	5	33	205	0	0
Fla., Tampa	April	8–17	2.29	1.2	2.0	*3.5	10	27	230	0	0
	May		2.18	1.3	3.4	*6.6	5	28	300	0	0
	June		2.15	1.1	2.2	NA	5	19	280	0	0
Ga., Atlanta	April	9–15	—	—	—	—	—	—	—	—	—
	May		—	—	—	—	—	—	—	—	—
	June		1.68	1.0	2.2	NA	5	35	125	0	0
Hawaii, Honululu	April	7–15	1.79	0.7	2.9	2	5	14	180	0	0
	May		NS	NS	NS	NS	NS	NS	NS	NS	NS
	June		1.52	0.8	1.8	1	15	23	100	0	0
Idaho, Idaho Falls	April	15–17	—	—	—	—	—	—	—	—	—
	May		1.92	1.3	2.9	2	5	77	345	0	0
	June		1.85	1.1	3.7	1	5	57	360	0	0
Ill., Chicago	April	8–15	1.54	0.9	2.3	1	5	23	155	0	0
	May		1.36	0.9	2.2	0	0	26	150	0	0
	June		1.33	0.9	1.9	1	5	20	120	0	0
Ind., Indianapolis	April	5–12	—	—	—	—	—	—	—	—	—
	May		—	—	—	—	—	—	—	—	—
	June		1.86	1.5	3.3	1	5	35	150	0	0
Iowa, Des Moines	April	6–13	—	—	—	—	—	—	—	—	—
	May		—	—	—	—	—	—	—	—	—
	June		2.01	1.6	2.4	NA	5	38	130	0	0
Kansas, Wichita	April	10–13	—	—	—	—	—	—	—	—	—
	May		—	—	—	—	—	—	—	—	—
	June		2.32	1.6	3.2	NA	5	32	160	0	0
Ky., Louisville	April	14–17	—	—	—	—	—	—	—	—	—
	May		—	—	—	—	—	—	—	—	—
	June		1.73	1.2	1.9	NA	5	40	95	0	0
La., New Orleans	April	8–17	2.66	1.7	4.3	*7.3	10	91	290	0	0
	May		2.60	1.7	3.9	*7.8	10	78	295	0	0
	June		2.60	1.6	3.1	NA	25	65	220	0	0
Maine, Portland	April	10–19	2.38	1.6	3.9	1	5	51	330	0	0
	May		2.30	1.4	3.5	1	5	47	305	0	0
	June		2.17	1.5	3.0	0	5	50	270	0	0
Md., Baltimore	April	7–12	—	—	—	—	—	—	—	—	—
	May		—	—	—	—	—	—	—	—	—
	June		1.73	1.4	2.8	NA	5	43	165	0	0
Mass., Boston	April	7–14	1.76	1.1	2.7	0	0	41	295	0	0
	May		2.17	1.3	3.6	1	5	38	330	0	0
	June		1.62	1.5	2.8	1	5	53	325	0	0
Mich., Detroit	April	7–15	—	—	—	—	—	—	—	—	—
	May		—	—	—	—	—	—	—	—	—
	June		2.07	1.7	2.9	1	5	35	195	0	0
Minn., Minneapolis	April	6–14	1.68	0.8	2.5	1	5	32	170	0	0
	May		1.98	1.2	2.8	1	50	20	150	0	0
	June		1.81	0.9	2.5	2	5	63	170	0	0
Miss., Columbia	April	12–18	1.90	1.7	2.5	*7.7	0	72	440	0	0
	May		2.04	2.0	2.8	*5.8	15	71	385	0	0
	June		1.88	1.7	2.3	NA	5	62	255	0	0
Mo., St. Louis	April	7–15	3.24	2.6	4.9	1	15	78	225	0	0
	May		2.32	1.6	3.5	1	5	51	150	0	0
	June		2.42	1.7	2.9	1	35	58	135	0	0
Mont., Helena	April	7–17	2.28	1.4	2.7	1	25	34	215	0	0
	May		2.05	1.0	2.5	1	10	27	205	0	0
	June		1.93	1.0	2.5	1	10	29	280	0	0

TABLE 2.—INSTITUTIONAL DAILY DIETARY INTAKE (BASED ON A COMPOSITE 7 CONSECUTIVE DAY SAMPLE IN EACH MONTH), SECOND QUARTER 1964—Continued

Location of institution	1964	Age (years)	Total weight (kg/day)	Calcium (grams per day)	Potassium (grams per day)	Radium-226 [a] (picocuries per day)	Strontium-89 (picocuries per day)	Strontium-90 (picocuries per day)	Cesium-137 (picocuries per day)	Barium-140 (picocuries per day)	Iodine-131 (picocuries per day)
Nebraska, Omaha	April	8–17	1.69	1.7	2.7	1	5	37	170	0	0
	May		2.29	2.1	3.0	3	5	50	285	0	0
	June		2.14	1.7	3.2	2	5	43	130	0	0
N. Mex., Albuquerque	April	5–12	2.03	1.4	2.6	1	5	20	70	0	0
	May		1.91	1.7	2.9	2	5	17	75	0	0
	June		2.00	1.6	2.6	1	10	38	60	0	0
N. Y., New York	April	8–18	1.55	1.7	2.3	2	0	24	180	0	0
	May		—	—	—	—	—	—	—	—	—
	June		—	—	—	—	—	—	—	—	—
N. C., Charlotte	April	9–18	—	—	—	—	—	—	—	—	—
	May		—	—	—	—	—	—	—	—	—
	June		2.26	1.6	2.9	NA	5	61	160	0	0
N. D., Fargo	April	12–16	—	—	—	—	—	—	—	—	—
	May		—	—	—	—	—	—	—	—	—
	June		1.48	0.7	1.9	3	5	22	190	0	0
Ohio, Cleveland	April	6–12	2.11	1.1	4.0	1	5	28	215	0	0
	May		1.88	1.2	2.7	1	5	26	190	0	0
	June		2.14	1.5	3.6	1	5	36	205	0	0
Okla., Oklahoma City	April	17–34	—	—	—	—	—	—	—	—	—
	May		1.90	1.4	3.1	*4.2	10	33	125	0	0
	June		1.67	1.0	1.7	NA	5	25	90	0	0
Penn., Pittsburgh	April	14–16	2.45	1.5	3.9	2	5	35	275	0	0
	May		2.25	1.3	3.4	1	5	44	225	0	0
	June		2.24	1.3	3.4	2	5	49	225	0	0
S. C., Charleston	April	8–14	—	—	—	—	—	—	—	—	—
	May		—	—	—	—	—	—	—	—	—
	June		1.27	0.6	1.9	NA	5	20	135	0	0
Tenn., Memphis	April	13–18	1.42	0.9	2.0	*4.0	10	41	85	0	0
	May		1.41	0.7	1.9	*3.7	5	34	75	0	0
	June		1.52	0.9	1.7	NA	5	27	75	0	0
Texas, Austin	April	13–17	1.74	0.8	1.9	*1.9	5	11	55	0	0
	May		2.00	0.9	2.3	*3.1	5	16	100	0	0
	June		1.65	0.7	1.5	NA	5	16	65	0	0
Utah, Salt Lake City	April	12–18	1.34	0.9	2.0	1	5	55	205	0	0
	May		1.81	1.6	2.5	2	20	49	225	0	0
	June		1.20	1.0	1.7	2	5	17	110	0	0
Vt., Burlington	April	7–13	1.89	1.0	2.8	1	5	28	220	0	0
	May		1.42	0.7	2.1	1	5	22	180	0	0
	June		1.26	0.8	2.3	0	5	35	175	0	0
Va., Norfolk	April	9–17	2.21	1.1	2.5	*4.5	10	37	140	0	0
	May		2.08	1.1	2.5	*6.9	5	31	175	0	0
	June		2.23	1.1	2.5	NA	5	40	165	0	0
Wash., Seattle	April	12–17	1.99	1.2	3.2	1	30	86	180	0	0
	May		1.88	1.1	2.4	1	40	51	170	0	0
	June		1.72	1.4	1.9	1	25	43	190	0	0
Wis., Milwaukee	April	10–17	—	—	—	—	—	—	—	—	—
	May		1.80	1.1	2.8	1	5	26	200	0	0
	June		1.87	1.3	3.0	1	5	36	180	0	0
Wyo., Laramie	April	11–17	2.05	1.2	3.1	2	5	31	185	0	0
	May		1.42	1.1	2.0	3	5	26	90	0	0
	June		1.67	1.0	2.3	1	5	53	135	0	0
Monthly Average	April		2.02	1.3	3.0	[e] 1	5	39	200	0	0
	May		1.92	1.3	2.8	[e] 1	10	38	195	0	0
	June		1.84	1.2	2.5	[e] 1	10	38	165	0	0

[a] Asterisk (*) to the left of number indicates *total Radium*. Average for radium-226 does not include total radium.
[b] Dash (—) indicates station not in operation.
[c] NA indicates no analysis.
[d] NS indicates no sample.
[e] Average for radium-226; does not include total radium.

RADIONUCLIDE LEVELS IN TEEN-AGE DIETS—A COMPARATIVE STUDY OF TWO SAMPLING PROGRAMS, FEBRUARY-JUNE 1964

Edmond J. Baratta[1] *and Edward R. Williams*[2]

As part of a continuation of previous contract studies, (1–6) the Division of Radiological Health contracted with Consumers Union, Inc., early in 1964 for a study of the levels of strontium–90, cesium–137, stable calcium, and stable potassium in the diets of teenagers in the following ten cities within the United States:

1. New Orleans, Louisiana
2. St. Louis, Missouri
3. Chicago, Illinois
4. Salt Lake City, Utah
5. Los Angeles, California
6. New York, New York
7. Buffalo, New York
8. Bismarck, North Dakota
9. Knoxville, Tennessee
10. Portland, Oregon

The first five of these cities also have institutions participating in the Institutional Total Diet Sampling Network of the Division of Radiological Health. The purpose of this paper is to report the data obtained from samples collected by the Consumers Union study, and to compare these results with similar observations under the Division's Total Diet Network.

Sampling procedure

Dietary samples from the Division's Total Diet Network represent the diet for seven days obtained by duplicating the meals of a different individual each day for varied age groups (*7*). Under the Consumers Union study, a total diet sample was collected from each listed city during February, April, May and June 1964. It consisted of a representative total diet for teenagers (12 to 18 years old) for a full week (21 consecutive meals plus snacks and beverages). The samples were collected for Consumers Union by home economists, who, on the basis of local surveys, prepared meals as nearly identical as possible in composition and weight to the average diet of male teenagers with hearty appetites. When available, fresh produce for the diets was purchased on the local market. Otherwise, frozen and canned items were used. Each daily menu contained exactly five cups of milk and three cups of water. To assure a representative cross section, a variety of brands of each food was bought.

The meals were prepared, including cooking and seasoning, as they would be for actual consumption. Inedible portions of the foods, such as bones, excess fats, skins, shells, pits and cores were discarded. After preparation, the samples from both studies were shipped to the Northeastern Radiological Health Laboratory in Winchester, Massachusetts, for analysis.

To evaluate the contribution of milk to the total radionuclide intake, duplicate samples were collected separately as well as in combination with the other foods in the total diet.

Analytical program and methods

Each sample, including the diet and separate fluid milk portion, was analyzed for strontium–90, cesium–137, stable potassium, and stable calcium. Strontium–90 content was determined by beta-counting the daughter product, yttrium–90, which had been chemically separated from the samples (*8*). Cesium–137 and potassium–40 were determined by gamma

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spectroscopy, using an expanded matrix solution (*9*). The stable potassium content was estimated from the amount of observed potassium–40. Calcium was determined by titration of oxalate (*10*). For quality control purposes, selected split samples were cross-checked with the Southeastern Radiological Health Laboratory in Montgomery, Alabama. Agreement between the two Laboratories was highly satisfactory.

Observed data

The strontium–90, cesium–137, and stable potassium and calcium contents of each sample, as well as the total weights consumed, are presented in table 1. The daily food consumption ranged from 2.77 to 4.76 kilograms, and stable calcium intakes ranged from 1.6 to 3.0 grams per day. Intake values for strontium–90 ranged from 19 to 101 picocuries per day; the lowest levels were observed in Los Angeles, and the highest in Bismarck. Cesium–137 intake values ranged from 160 to 720 picocuries per day; the lowest levels were observed in Los Angeles, and the highest in Portland.

Comparison of Consumers Union data with Institutional Total Diet results

As mentioned earlier, five of the cities surveyed in the Consumers Union study also serve as sampling locations for the DRH Institutional Total Diet Sampling Network. It should be noted that the latter Network represents actual average diets for a somewhat younger age group having a less hearty diet than that represented in the Consumers Union studies. It may also be observed that the total intake of this group is less.

The data have also been analyzed on the basis of the strontium–90 to stable calcium and of the cesium–137 to stable potassium ratios, which permits a comparison of data independent of the amount consumed. The ratios of strontium–90 to stable calcium for the samples from the five cities common to the two studies are presented in table 2. Similarly, the ratios of cesium–137 to stable potassium are shown in table 3. Average values for these ratios for both the Consumers Union study and the Institutional Diet Network are plotted in figure 1. The strontium–90 data show good agreement except for the February and April samples from St. Louis, and the February sample from Los Angeles. In general, the cesium–137 data show the same order of agreement as the strontium–90 data.

To evaluate milk as a source of stable calcium in the total diets collected under the Consumers Union study, the percentages of calcium contributed to the sampled diets from the milk component have been computed (table 4). Similarly, table 5 presents data on the percentage of strontium–90 contributed to the total diet by the milk component.

TABLE 1.—AVERAGE DAILY TEEN-AGE DIETARY INTAKE,[1] CONSUMERS UNION STUDY, FEBRUARY-JUNE 1964

City	Weight (kg/day)				Calcium (g/day)				Sr-90 (pc/day)				Cs-137 (pc/day)				K (g/day)			
	Feb	Apr	May	June	Feb	Apr	May	June	Feb	Apr	May	June	Feb	Apr	May	June	Feb	Apr	May	June
New York, N. Y	3.43	4.70	3.57	3.59	2.2	2.6	1.8	2.0	55	61	56	72	280	460	330	420	5.25	7.05	5.07	4.52
Buffalo, N. Y	3.79	3.97	3.24	3.31	2.1	2.0	1.8	1.9	50	59	46	59	360	380	310	330	5.08	5.60	4.18	3.54
New Orleans, La	2.91	3.20	3.89	3.09	1.9	2.0	2.1	1.9	67	82	92	85	280	410	370	260	3.20	3.48	4.90	3.55
St. Louis, Mo	3.91	4.11	3.39	3.64	2.3	2.3	2.0	2.3	52	42	56	67	290	350	270	280	5.38	5.35	4.75	4.00
Chicago, Ill	3.63	4.33	3.63	3.66	2.4	2.4	1.9	2.2	43	47	41	44	280	370	320	260	4.32	5.80	4.97	4.80
Bismarck, N. D	3.27	3.64	3.17	2.77	2.2	2.1	2.0	1.6	84	92	101	83	405	440	350	320	4.38	5.27	4.03	3.96
Knoxville, Tenn	4.24	4.13	3.41	4.37	2.8	2.4	2.3	3.2	66	66	91	97	360	410	410	340	5.34	5.74	5.90	6.03
Salt Lake City, Utah	3.70	4.27	3.43	3.54	2.4	2.4	2.0	2.2	52	55	48	47	460	600	420	420	6.00	6.58	4.15	4.81
Portland, Ore	4.37	4.37	4.23	4.20	3.0	2.3	2.6	2.3	66	80	83	71	720	700	700	550	7.14	6.47	6.18	5.04
Los Angeles, Calif	4.76	4.39	4.01	3.89	2.5	2.1	2.3	1.9	28	26	31	19	260	220	260	160	7.66	6.80	6.02	5.41
Average	3.80	4.11	3.60	3.61	2.4	2.3	2.1	2.2	56	61	65	61	370	433	343	334	5.38	5.81	5.02	4.57

[1] Average Based on Seven Days.

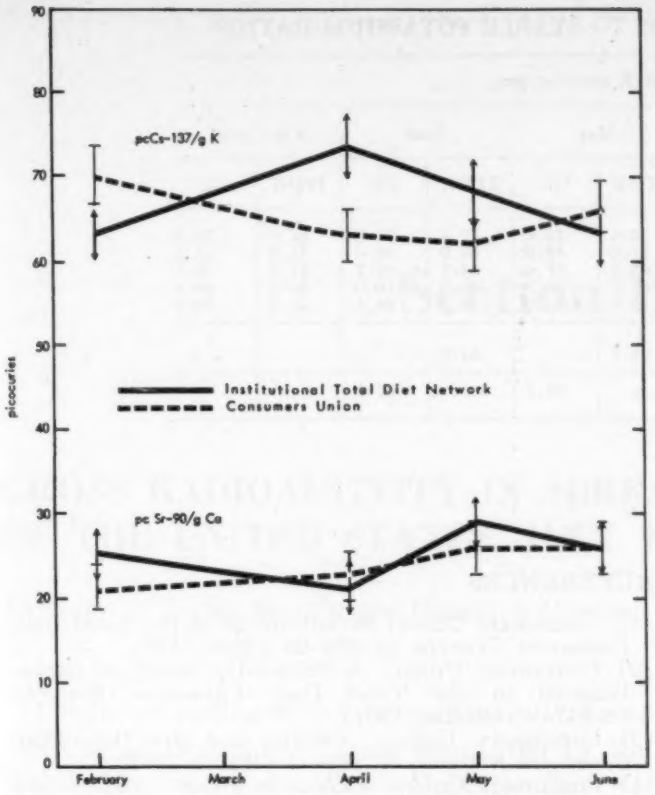

FIGURE 1.—COMPARISON OF AVERAGE RATIOS (pc Cs–137/gK; pc Sr–90/g Ca) IN INSTITUTIONAL TOTAL DIET NETWORK AND CONSUMER'S UNION SAMPLES FOR FIVE CITIES (NEW ORLEANS, ST. LOUIS, CHICAGO, SALT LAKE CITY, AND LOS ANGELES) IN 1964 (Errors at the 95 percent confidence level are approximated by vertical bars)

Discussion

Comparison of the data for 1964 with those observed during previous studies by Consumers Union (*6*) shows that in three cities (Bismarck, Buffalo, and New York) the ratios of strontium–90 to stable calcium during 1964 were at least twice as high as they had been during 1963. The average ratio of strontium–90 to stable calcium in the nine cities included in studies during both 1963 and 1964 showed an increase of 25 percent. The average ratios of cesium–137 to stable potassium in two cities (Los Angeles, and Bismarck) were three times as high in 1964 as in 1963; the average total intake of cesium–137 in the nine cities for 1964 was twice that observed during the same months in 1963.

Though the average total intake for both strontium–90 and cesium–137 increased immediately after February 1964 (table 1), the *rates of increase* in 1964 were much less than in 1963. By June 1964 the average strontium–90 to stable calcium ratio in the diets for the nine cities was no higher than it had been in June 1963. The average total daily intake of cesium–137 in June 1964 was only 60 percent higher than in the corresponding month during 1963.

This study tends to indicate that, for a given city, the ratios of strontium–90 to stable calcium and of cesium–137 to stable potassium were essentially the same for samples obtained through the Consumers Union study and the Institutional Total Diet Network. Therefore, it appears that the differences in daily intakes for radionuclides reported by the two Networks are mainly due to differences in the amounts of food consumed.

TABLE 2.—COMPARISON OF STRONTIUM-90 TO STABLE CALCIUM RATIOS

Sampling site	Sr-90/Ca (pc/gm)									
	February		April		May		June		4 mo. aver.	
	ITDN [1]	CU [2]	ITDN [1]	CU [2]	ITDN [1]	CU [2]	ITDN [1]	CU [2]	ITDN [1]	CU [2]
New Orleans	40.6	34.7	—	41.1	45.9	42.9	40.6	44.4	42.3	40.7
St. Louis	48.2	22.4	30.0	18.1	31.9	28.1	34.1	29.0	36.0	24.4
Chicago	11.3	17.9	23.0	19.3	28.9	21.9	22.2	19.7	21.3	19.7
Salt Lake City	23.3	22.2	25.0	23.0	30.6	24.1	17.0	21.3	23.6	22.6
Los Angeles	4.2	10.9	11.3	12.6	10.0	13.7	16.3	10.0	10.4	11.8
ITDN:	25.5		21.4		29.5		26.0			
CU:		21.6		22.8		26.1		26.0		

[1] Institutional Total Diet Network
[2] Consumers Union

TABLE 3.—COMPARISON OF CESIUM-137 TO STABLE POTASSIUM RATIOS

Sampling site	Cs-137/K ratio (pc/gm)									
	February		April		May		June		4 mo. aver.	
	ITDN [1]	CU [2]	ITDN	CU	ITDN	CU	ITDN	CU	ITDN	CU
New Orleans	86.2	92.5	116.2	67.4	75.4	75.6	72.4	71.0	84.5	76.6
St. Louis	53.8	46.2	66.0	45.9	57.6	42.8	69.9	46.6	61.8	45.3
Chicago	64.3	75.9	64.4	67.4	63.4	67.4	54.7	66.7	61.7	69.3
Salt Lake City	77.2	95.4	91.0	102.5	101.2	90.0	86.6	110.0	89.0	99.4
Los Angeles	33.5	40.9	31.7	33.3	43.1	34.5	30.0	36.1	34.5	36.2
Average ITDN:	63.0		73.9		68.1		62.7			
C:		70.2		63.3		62.1		66.1		

[1] Institutional Total Diet Network.
[2] Consumers Union.

TABLE 4.—PERCENT OF CALCIUM INTAKE CONTRIBUTED BY MILK, CONSUMERS UNION STUDY

Sampling Site	February	April	May	June
New York	67	54	89	65
Buffalo	67	70	78	68
New Orleans	79	75	71	74
St. Louis	61	61	70	61
Chicago	58	58	74	59
Bismarck	64	67	70	88
Knoxville	57	58	61	41
Salt Lake City	63	58	70	59
Portland	53	65	58	61
Los Angeles	56	67	57	68
Average	62	63	70	64

TABLE 5.—PERCENT OF STRONTIUM-90 INTAKE CONTRIBUTED BY MILK, CONSUMERS UNION STUDY

Sampling Site	February	April	May	June
New York	45	44	66	50
Buffalo	46	37	48	66
New Orleans	[a] 1.01	80	80	73
St. Louis	46	64	60	64
Chicago	63	32	69	57
Bismarck	74	57	79	[a] 1.05
Knoxville	53	74	74	45
Salt Lake City	62	60	71	66
Portland	45	59	76	66
Los Angeles	25	46	29	32
Average	56	55	65	62

[a] Under ideal conditions, these values should not have exceeded unity—the condition where fluid milk serves as essentially the sole source of Sr-90 in the diet. These higher values undoubtedly are the result of analytical errors and the fact that the total diets and milk components were sampled and analyzed separately.

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Section III—Water

GROSS RADIOACTIVITY IN SURFACE WATERS OF THE UNITED STATES, JULY 1964

Division of Water Supply and Pollution Control, Public Health Service

Levels of radioactivity in surface waters of the United States have been monitored by the Public Health Service Water Pollution Surveillance System since its initiation in 1957. Beginning with the establishment of 50 sampling points, this system has expanded to 131 stations as of December 1, 1964. These are operated jointly with other Federal, State, and local agencies, and industry. Samples are taken from surface waters of all major U. S. river basins for physical, chemical, biological, and radiological analyses. These data can be used for evaluating sources of radioactivity which may affect specific domestic, commercial, and recreational uses of surface water. Further, the system provides background information necessary for recognizing pollution and water quality trends and for determining levels of radioactivity to which the population may be exposed. Data assembled through the system and exact locations of sampling points are published in annual compilations (*1–7*).

Sampling Procedures

The participating agencies collect one-liter "grab" samples each week and ship them "as is" to the Surveillance System Laboratory in Cincinnati for analysis. Gross alpha and gross beta radioactivity determinations on the suspended and dissolved solids are performed as frequently as deemed necessary.

Presently, gross alpha and beta determinations are made on either monthly composites of the weekly samples or on each weekly sample. Weekly alpha and beta determinations are scheduled for stations located downstream from known potential sources of radioactive waste. Weekly analyses are also conducted at all newly established stations for the first year of operation.

Normally, samples are counted within two weeks following collection or within one week after compositing. The decay of activity is followed on each sample for which the first analysis shows unusually high activity. Also, if a recount indicates that the original analysis was questionable, values based on recounting are recorded. All results are reported for the time of counting and are not extrapolated to the time of collection.

Strontium–90 analyses are performed on total solids of three-month composites of the weekly samples. The most recent strontium–90 results are presented in the December 1964 issue of *RHD*.

Analytical Methods

The analytical method used for determining gross alpha and beta radioactivity is described in the eleventh edition of "Standard Methods for the Examination of Water and Wastewater" (*8*). Suspended and dissolved solids are separated by passing the sample through a mem-

brane filter (type HA) with a pore size of 0.45 micron. Planchets are then prepared for counting the dissolved solids (in the filtrate) and the suspended solids (on the charred membrane filter) in an internal proportional counter. Reference sources of U_3O_8, which give a known count rate if the instrument is in proper calibration, are used for daily checking of the counter.

Results

Table I presents July 1964 results of alpha and beta analysis of U.S. surface waters. The stations on a river are arranged in the table according to their relative location on the river, the first stations listed being closest to the headwaters. These data are preliminary. Replicate analyses of some samples as well as some analyses incomplete at the time of this report will be included in the system's "Annual Compilation of Data" (*7*). The figures for gross alpha and gross beta radioactivity represent either determinations on composite samples or means of weekly determinations where composites were not made. The monthly means are reported to the nearest pc/liter. When all samples have zero pc/liter, the mean is reported as zero; when the calculated mean is between zero and 0.5, the mean is reported as <1 pc/liter.

A geographical perspective of the radioactivity in surface water is obtained from the numbers printed near the stations as shown in figure 1, which gives the June 1964 average total beta activity in suspended-plus-dissolved solids in raw water collected at each station. Gross radioactivity results for the years 1957–1962 have been summarized by Weaver *et al* (*9*). Floyd and Weaver summarized the strontium–90 results obtained from 1959 through 1963 in the August 1964 issue of *RHD* (*10*).

TABLE 1.—RADIOACTIVITY IN RAW SURFACE WATERS, JULY 1964

[Average concentrations in pc/liter]

Station	Beta activity			Alpha activity		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total
Allegheny River:						
Pittsbugh, Pa						
Animas River:						
Cedar Hill, N. Mex	<1	14	14	<1	5	5
Apalachicola River:						
Chattahoochee, Fla	2	13	15	0	0	0
Arkansas River:						
Coolidge, Kansas	7	30	37	1	14	15
Ponca City, Okla	39	40	79	1	0	1
Atchafalaya River:						
Morgan City, La	36	21	57	7	2	9
Bear River:						
Preston, Idaho	6	22	28	1	4	5
Big Horn River:						
Hardin, Mont	43	22	65	11	7	18
Chena River:						
Fairbanks, Alaska	4	12	16	0	1	1
Clinch River:						
Clinton, Tenn	1	9	10	0	0	0
Kingston, Tenn	11	39	50	0	5	5
Colorado River:						
Loma, Colo	10	20	30	1	9	10
Page, Ariz	12	52	64	2	11	13
Parker Dam, Calif-Ariz	2	18	20	0	5	5
Columbia River:						
Wenatchee, Wash	2	8	10	0	0	0
Pasco, Wash	22	116	138	0	<1	<1
Clatskanie, Ore	31	69	100	<1	<1	<1
Connecticut River:						
Enfield Dam, Conn	6	14	20	0	0	0
Delaware River:						
Philadelphia, Pa	5	15	20	0	1	1
Great Lakes:						
Duluth, Minn	2	9	11	0	0	0
Illinois River:						
Grafton, Ill	7	21	28	1	3	4
Kansas River:						
De Soto, Kans	52	34	86	5	0	5
Maumee River:						
Toledo, Ohio	1	21	22	0	1	1
Mississippi River:						
St. Paul, Minn	3	32	35	0	3	3
E. St. Louis, Ill	40	28	68	11	1	12
New Roads, La	50	47	97	6	3	9
New Orleans, La	19	21	40	4	2	6
Missouri River:						
Williston, N. Dak	8	16	24	2	2	4
St. Joseph, Mo	116	36	152	30	3	33
North Platte River:						
Henry, Nebr	13	38	51	1	15	16
Ohio River:						
Toronto, Ohio	1	14	15	0	0	0
Cairo, Ill	8	17	25	1	1	2
Platte River:						
Plattsmouth, Nebr	83	31	114	9	4	13
Potomac River:						
Washington, D.C	3	12	15	0	0	0
Red River, North:						
Grand Forks, N. Dak	11	53	64	0	4	4
Red River, South:						
Alexandria, La	7	40	47	1	0	1
Rio Grande River:						
El Paso, Tex	55	29	84	11	3	14
Laredo, Tex	18	38	56	3	4	7
San Joaquin River:						
Vernalis, Calif	9	16	25	2	8	10
San Juan River:						
Shiprock, N. Mex	170	24	194	28	5	33
Savannah River:						
Port Wentworth, Ga	6	18	24	<1	0	<1
Snake River:						
Wawawai, Wash	5	8	13	1	0	1
South Platte River:						
Julesburg, Colo	5	77	82	0	26	26
Yellowstone River:						
Sidney, Mont	80	16	96	13	2	15
Maximum	170	116	194	30	14	33
Minimum	<1	8	10	0	0	0

Note: These data are preliminary; reanalysis of some samples may be made and additional analysis not completed at the time of the report may become available. For final data, one should consult the system's annual report (*7*).

FIGURE 1.—SAMPLING LOCATIONS AND TOTAL BETA ACTIVITY (pc/liter) IN SURFACE WATERS, JULY 1964

Discussion

The monthly dissolved beta activity averages exceeded 100 pc/liter at only one station, the Pasco, Washington station on the Columbia River.

The dissolved alpha activity, which is associated with the dissolving of natural surface minerals by water, ranged from zero to 14 pc/liter. Of all stations, four stations, each on a different river, had monthly average dissolved alpha activity greater than 10 pc/liter.

The radioactivity associated with dissolved solids provides a rough indication of the levels which could occur in treated water, since nearly all suspended matter is removed by the treatment process (*11*). The Public Health Service Drinking Water Standards state that in the absence of strontium–90 and alpha emitters,[1] a water supply is acceptable when the gross beta concentration does not exceed 1,000 pc/liter (*12*).

[1] Absence is taken here to mean a negligibly small fraction of the specific limits of 3 pc/liter and 10 pc/liter for unidentified alpha emitters and strontium–90, respectively.

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[2] Single free copies of this publication may be obtained from: Public Inquiries Branch, Public Health Service, U. S. Department of Health, Education, and Welfare, Washington, D. C. 20201.

RADIOACTIVITY IN FLORIDA WATERS, 1962-1963[1]

Bureau of Environmental Engineering
Florida State Board of Health

The Florida State Board of Health samples raw surface water from locations in 13 hydrological sub-basins. In nine of these sub-basins, raw ground water is also sampled. The samples, analyzed for alpha and beta radioactivity, are collected on a variable frequency.

Figure 1 shows the approximate area of the surface water sub-basins from which samples are obtained. Average gross alpha and beta radioactivity in raw surface water during 1962 and 1963 are presented in table 1. For comparison, table 2 gives the average gross alpha and beta radioactivity in ground water during 1962 and 1963.

In addition to the sampling being done by the Florida State Board of Health, the Sanitary Engineering Research Laboratory, University of Florida, samples raw surface water and water supplies in Alachua County and analyzes the samples for gross alpha and gross beta radioactivity. Samples are taken monthly from each sampling point with the exception of the City of Gainesville's raw water, which is sampled daily. Data are summarized in table 3 as quarterly and yearly averages.

[1] Data taken from "Report of Florida Radiological Data, Environmental Monitoring Programs, 1962" and "*Ibid*, 1963." Florida State Board of Health, Bureau of Preventable Diseases, Division of Radiological and Occupational Health, Jacksonville, Florida.

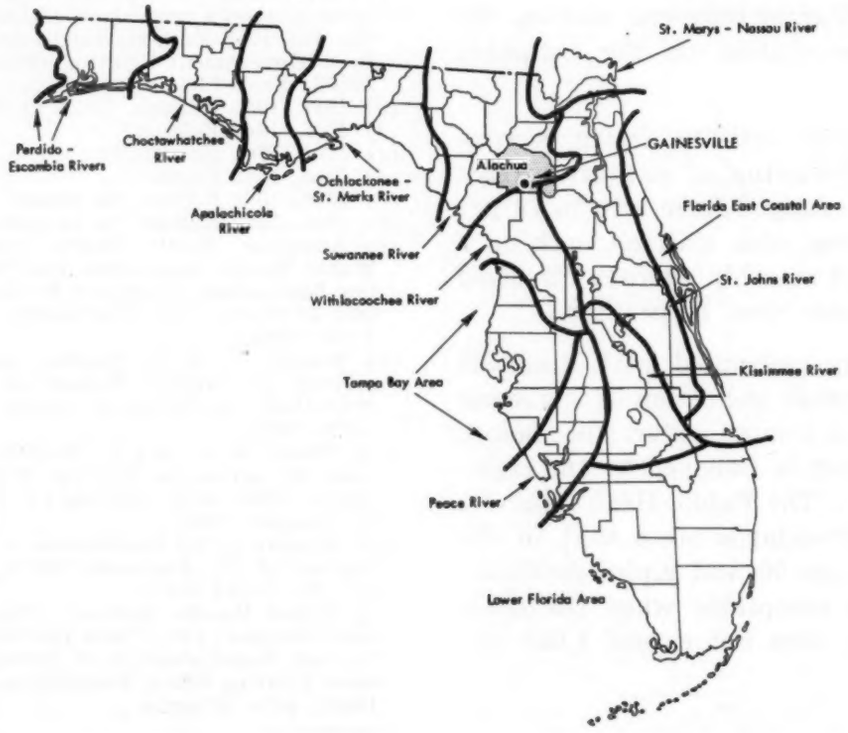

FIGURE 1.—HYDROLOGICAL SURFACE WATER SUB-BASINS IN FLORIDA

TABLE 1.—GROSS ALPHA AND BETA RADIOACTIVITY IN RAW SURFACE WATER IN FLORIDA, 1962-1963

[Contrations in pc/liter]

Sub-Basin	Quarter 1962								1962 average	
	First		Second		Third		Fourth			
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta
Apalachicola River	5.0 (6)	63.5 (6)			0.3 (7)	15.4 (7)			2.5 (13)	37.6 (13)
Choctawhatchee River	5.2 (7)	63.0 (7)			0.4 (9)	25.3 (9)			2.5 (16)	41.8 (16)
Florida East Coastal Area			2.2 (1)	17.9 (1)					2.2 (1)	17.9 (1)
Kissimmee River	5.1 (1)	10.0 (1)			0.3 (2)	39.7 (2)	Bkg. (2)	28.8 (2)	1.1 (5)	29.4 (5)
Lower Florida Area	2.3 (6)	29.1 (6)					0.2 (15)	36.6 (15)	0.8 (21)	34.5 (21)
Ochlockonee—St. Marks River	0.2 (8)	25.2 (8)					0.2 (19)	12.4 (19)	0.2 (27)	16.2 (27)
Peace River							0.1 (6)	21.9 (6)	0.1 (6)	21.9 (6)
Perdido—Escambia River	7.7 (6)	105.5 (6)			3.0 (8)	44.8 (8)			5.0 (14)	70.8 (14)
St. Johns River	1.0 (1)	23.5 (1)	2.5 (1)	32.8 (1)	0.1 (2)	28.4 (2)	0.1 (3)	54.3 (3)	0.6 (7)	39.4 (7)
St. Marys—Nassau River							Bkg. (2)	52.7 (2)	Bkg. (2)	52.7 (2)
Tampa Bay Area							0.2 (12)	29.4 (12)	0.2 (12)	29.4 (12)
Withlacoochee and Wacasassa Rivers							0.2 (2)	20.3 (2)	0.2 (2)	20.3 (2)
Average	3.8 (35)	53.3 (35)	2.4 (2)	25.4 (2)	1.1 (28)	29.6 (28)	0.2 (61)	26.8 (61)	1.4 (126)	34.8 (126)

Sub-Basin	Quarter 1963								1963 average	
	First		Second		Third		Fourth			
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta
Apalachicola River			0.1 (6)	29.9 (6)	0.4 (4)	38.4 (4)			0.2 (10)	33.3 (10)
Choctawhatchee River	0.1 (9)	25.5 (9)			Bkg. (5)	28.2 (5)	0.5 (3)	37.5 (3)	0.1 (17)	28.4 (17)
Florida East Coastal Area			0.2 (2)	120.0 (2)			Bkg. (1)	10.5 (1)	0.1 (3)	83.5 (3)
Kissimmee River			0.2 (3)	109.8 (3)	1.9 (1)	198.4 (1)	0.2 (3)	45.4 (3)	0.4 (7)	94.9 (7)
Lower Florida Area			0.2 (9)	62.4 (9)	0.4 (6)	86.1 (6)	0.6 (1)	87.9 (1)	0.3 (16)	72.9 (16)
Ochlockonee—St. Marks River	Bkg. (21)	73.6 (21)	0.2 (6)	82.8 (6)	0.5 (12)	62.0 (12)			0.2 (39)	71.4 (39)
Peace River			0.2 (6)	138.7 (6)	0.6 (1)	95.3 (1)	0.3 (2)	48.1 (2)	0.3 (9)	113.7 (9)
Perdido—Escambia River	Bkg. (7)	38.4 (7)	Bkg. (1)	27.8 (1)	0.2 (4)	44.7 (4)	0.4 (2)	20.7 (2)	0.1 (14)	36.9 (14)
St. Johns River	0.1 (7)	54.2 (7)	0.2 (6)	93.2 (6)	0.4 (16)	135.6 (16)	0.3 (17)	89.1 (17)	0.3 (46)	100.5 (46)
St. Marys—Nassau River					0.1 (1)	147.1 (1)			0.1 (1)	147.1 (1)
Suwannee River	0.1 (7)	89.4 (7)	0.9 (2)	156.0 (2)	0.3 (12)	113.5 (12)			0.3 (21)	109.5 (21)
Tampa Bay Area			0.1 (14)	59.8 (14)	1.8 (3)	89.4 (3)	0.3 (4)	69.6 (4)	0.4 (21)	65.9 (21)
Withlacoochee River	0.1 (10)	30.2 (10)					0.2 (5)	52.0 (5)	0.1 (15)	37.5 (15)
Average	0.1 (61)	54.9 (61)	0.2 (55)	79.5 (55)	0.4 (65)	90.5 (65)	0.3 (38)	66.6 (38)	0.2 (219)	73.7 (219)

Note: Numbers in parentheses indicate number of samples.

The yearly average beta activity in ground water was 2 to 10 times lower than that in surface water in 1962 and 1963. This beta activity can be attributed to fallout. The alpha activity which is attributed to natural activity of minerals is very nearly the same for ground and surface water. Fallout is, therefore, clearly evident by comparison of gross beta radioactivity in raw surface water and raw well water for both 1962 and 1963. However, no obvious trend directly related to fallout from 1962 weapons testing is indicated by the data obtained by water sampling programs.

The annual average gross beta concentrations in surface water for 1962 are about one half of the averages for 1963 in most basins. The gross beta concentrations in ground water for 1963 were usually not very different from those in 1962.

The average gross beta radioactivity in water supplies is well below the standard (*1*) for gross beta radioactivity in drinking water (1,000 pc/liter), as is average gross alpha radioactivity when compared to its standard for drinking water (3 pc/liter with radium present).

TABLE 2.—GROSS ALPHA AND BETA RADIOACTIVITY IN UNTREATED WELL WATER IN FLORIDA, 1962–1963

[Concentrations in pc/liter]

Sub-Basin	Quarter 1962								1962 average	
	First		Second		Third		Fourth			
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta
Apalachicola River					0.1 (1)	7.5 (1)			0.1 (1)	7.5 (1)
Choctawatchee River	1.8 (1)	5.5 (1)			0.7 (5)	17.2 (5)			0.9 (6)	15.3 (6)
Kissimmee River							Bkg. (1)	5.8 (1)	Bkg. (1)	5.8 (1)
Lower Florida Area	0.1 (3)	20.7 (3)					0.2 (8)	34.9 (8)	0.4 (11)	31.0 (11)
Ochlockonee—St. Marks River	0.3 (4)	Bkg. (4)					0.1 (5)	4.0 (5)	0.2 (9)	2.2 (9)
Peace River							Bkg. (1)	61.7 (1)	Bkg. (1)	61.7 (1)
Perdido—Escambia Rivers	1.9 (1)	6.3 (1)			0.6 (3)	8.2 (3)			0.9 (4)	7.7 (4)
Tampa Bay Area			4.2 (1)	19.4 (1)			0.3 (5)	10.8 (5)	1.0 (6)	12.2 (6)
Withlacoochee and Wacasassa Rivers							Bkg. (2)	5.0 (2)	Bkg. (2)	5.0 (2)
Average	0.8 (9)	8.2 (9)	4.2 (1)	19.4 (1)	0.5 (9)	12.3 (9)	0.2 (22)	18.6 (22)	0.5 (41)	14.9 (41)

Sub-Basin	Quarter 1963								1963 average	
	First		Second		Third		Fourth			
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta
Choctawatchee River	0.1 (1)	10.7 (1)							0.1 (1)	10.7 (1)
Florida East Coastal Area	0.2 (2)	6.3 (2)	0.1 (3)	13.1 (3)	0.4 (1)	10.7 (1)	0.1 (2)	12.4 (2)	0.2 (8)	10.9 (8)
Lower Florida Area	Bkg. (1)	6.4 (1)	0.5 (5)	26.6 (5)	0.3 (2)	14.6 (2)	Bkg. (1)	8.1 (1)	0.3 (9)	19.6 (9)
Ochlockonee—St. Marks River	Bkg. (5)	12.5 (5)							Bkg. (5)	21.5 (5)
Perdido—Escambia Rivers			0.2 (2)	8.6 (2)			0.3 (3)	10.9 (3)	0.3 (5)	10.0 (5)
St. Johns River	0.2 (1)	7.6 (1)	0.3 (2)	89.2 (2)	0.1 (2)	31.5 (2)	0.2 (2)	7.1 (2)	0.2 (7)	37.6 (7)
Suwannee River					0.6 (1)	11.7 (1)			0.6 (1)	11.7 (1)
Tampa Bay Area			0.3 (1)	11.3 (1)					0.3 (1)	11.3 (1)
Withlacoochee River	0.2 (5)	8.3 (5)					0.3 (1)	13.5 (1)	0.2 (6)	9.2 (6)
Average	0.1 (15)	12.4 (15)	0.3 (13)	29.2 (13)	0.3 (6)	19.1 (6)	0.2 (9)	10.3 (9)	0.2 (43)	18.0 (43)

Note: Number in parentheses indicates number of samples.

TABLE 3.—GROSS ALPHA AND BETA RADIOACTIVITY IN RAW WATER IN FLORIDA IN 1962 AND 1963

[Concentrations in pc/liter]

Location	Quarter								Yearly average	
	First		Second		Third		Fourth			
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta
1962										
Alachua County: (19 sampling locations)	2.0 (57)	62.1	0.9 (57)	35.6	1.9 (57)	33.5	1.2 (38)	49.0	1.6 (209)	45.0
City of Gainesville	0.3 (68)	11.9	0.5 (73)	22.4	0.5 (78)	11.6	0.4 (89)	13.3	0.4 (308)	14.5
1963										
Alachua County: (19 sampling locations)	1.7 (57)	67.3	0.8 (19)	79.8	1.0 (57)	43.3	0.6 (57)	22.4	1.1 (190)	47.7
City of Gainesville	0.7 (84)	19.3	0.3 (81)	18.8	0.2 (81)	9.6	0.4 (90)	5.6	0.4 (336)	13.2

Note: Numbers in parentheses indicate number of samples.

REFERENCE

(1) Public Health Service: *Public Health Service Drinking Water Standards, Revised 1962.* Publication No. 956, U. S. Government Printing Office, Washington, D.C., 1963. Price: 30 cents.

RADIOACTIVITY IN MINNESOTA SURFACE WATER SUPPLIES, JANUARY—JUNE 1964[1]

Division of Environmental Health
Minnesota Department of Health

The analysis of various Minnesota waters for radioactivity concentration was initiated in 1956 as part of the Minnesota Water Pollution Control Program. This program was expanded in 1958 to include most of the municipal surface water supplies in the State as well as selected lakes throughout the State.

As many as 25 surface streams and lakes involving 74 stations have been sampled, but six surface streams and lakes are now sampled routinely (see figure 1). "Grab" samples of raw and treated water are collected weekly at each station. No raw water is collected from the Minneapolis supply.

The samples are forwarded to the Division's laboratory where they are analyzed for gross beta activity. A 250-ml sample of water is evaporated at 75° C. from a two-inch planchet. The solid residue (suspended plus dissolved solids) is fixed by adding lucite in acetone. Afterwards, this sample is counted for beta activity with an internal proportional counter. Counter standardization is accomplished by adding known amounts of thallium–204 standard to solutions containing the normal range of solids.

Table 1 shows the monthly average gross beta activity in Minnesota surface water from January–June 1964. The minimum reported level is a convenient low value not normally exceeded by one standard deviation; this is 15 pc/liter

FIGURE 1.—SURFACE WATER SAMPLING LOCATIONS

at present. In averaging, the value 7 pc/liter is used for samples having less than the minimum detectable value.

The data obtained on gross beta activity in Minnesota surface waters show a variation of concentrations, with no readily apparent trends. Variation in precipitation and flow rates of streams could contribute to this variation. Monthly averages of gross beta radioactivity in Minnesota raw surface waters ranged from 7 to 78 pc/liter. Treated water in most cases contained less beta activity than the corresponding raw water.

[1] Data and information from "Survey of Environmental Radioactivity, January–June 1964." State of Minnesota Department of Public Health, University Campus, Minneapolis 14, Minnesota 55440.

TABLE 1.—TOTAL BETA CONCENTRATIONS IN MINNESOTA RAW AND TREATED WATER FROM SURFACE SUPPLIES, JANUARY–JUNE 1964

[Monthly average concentrations in pc/liter]

Town and water source	Type of water	Jan	Feb	Mar	April	May	June
East Grand Forks, Red Lake River	Raw	22	22	26	42	61	64
	Treated	7	7	11	14	30	32
Eveleth, St. Mary's Lake	Raw	23	20	36	16	23	31
	Treated	20	24	20	10	24	18
Fairmount, Budd Lake	Raw	40	28	25	25	20	14
	Treated	13	20	7	7	7	10
Hallock, Two Rivers South Fork	Raw	39	45	32	53	62	78
	Treated	23	10	18	15	18	22
Minneapolis Tap Water	Raw	[a] —	—	—	—	—	—
	Treated	12	7	9	10	16	13
St. Paul, Vadnais Chain of Lakes	Raw	23	12	24	18	23	11
	Treated	18	7	7	7	14	11

[a] Dash indicates no sample.

Previous coverage in *Radiological Health Data:*

Period	Issue
October 1957–August 1959	*April 1960*
August 1959–April 1962	*August 1962*
April 1962–November 1962	*April 1963*
December 1962–June 1963	*November 1963*
July–December 1963	*June 1964*

Section IV—Other Data

MICHIGAN DEPARTMENT OF HEALTH REACTOR ENVIRONMENTAL SURVEILLANCE PROGRAM—A SUMMARY REPORT

G. A. Jacobson, D. E. Van Farowe, J. M. Hennigan, R. C. Bennett

INTRODUCTION

In January 1955 the Atomic Energy Commission began a power reactor demonstration program to promote the commercial use of nuclear power. Since that time two power reactors have been built in Michigan.

The Enrico Fermi power reactor, built by the Power Reactor Development Corporation, is located on the shores of Lake Erie about ten miles northeast of Monroe and 30 miles southwest of Detroit. It is a fast breeder type reactor, fueled with enriched uranium, cooled with liquid sodium, and designed for an initial capacity of 100 megawatts of electrical power. Although construction was begun in 1957, because of several technical difficulties the reactor did not become operational until August 23, 1963.

The Big Point power reactor, built by Consumers Power Company, is located on the shores of Lake Michigan about 5 miles northeast of Charlevoix. It is a pressurized boiling water reactor, fueled with slightly enriched uranium and designed for an initial capacity of 50 megawatts of electrical power. Construction at Big Rock Point began in the spring of 1960, and the reactor became operational on September 27, 1962.

The Michigan Department of Health, in carrying out its responsibilities to protect the health of the people of Michigan, has worked closely with both the Power Reactor Development Corporation and the Consumers Power Company in reviewing safety factors during the construction of the reactors. A basic concern in reactor design is the prevention of the release of radioactive materials to the environment under any but carefully controlled and monitored conditions. Tolerance standards for this release have been carefully established (*1*) (*2*). As a safety measure the reactors are encased in high integrity steel containment enclosures designed to limit any accidental release of radioactivity. However, it is not the purpose of this paper to go into details of the safeguards built into the design of these plants, but instead to discuss elements of the planning, initiating, and carrying out a monitoring program, and to present some typical monitoring data.

Essentially, a monitoring program is a means of substantiating whether or not control mechanisms are operating properly. To do this it is necessary to be able to detect radioactive materials that have been released into the environs in excess of allowable limits referenced previously.

The monitoring program was established by the department with the following objectives:

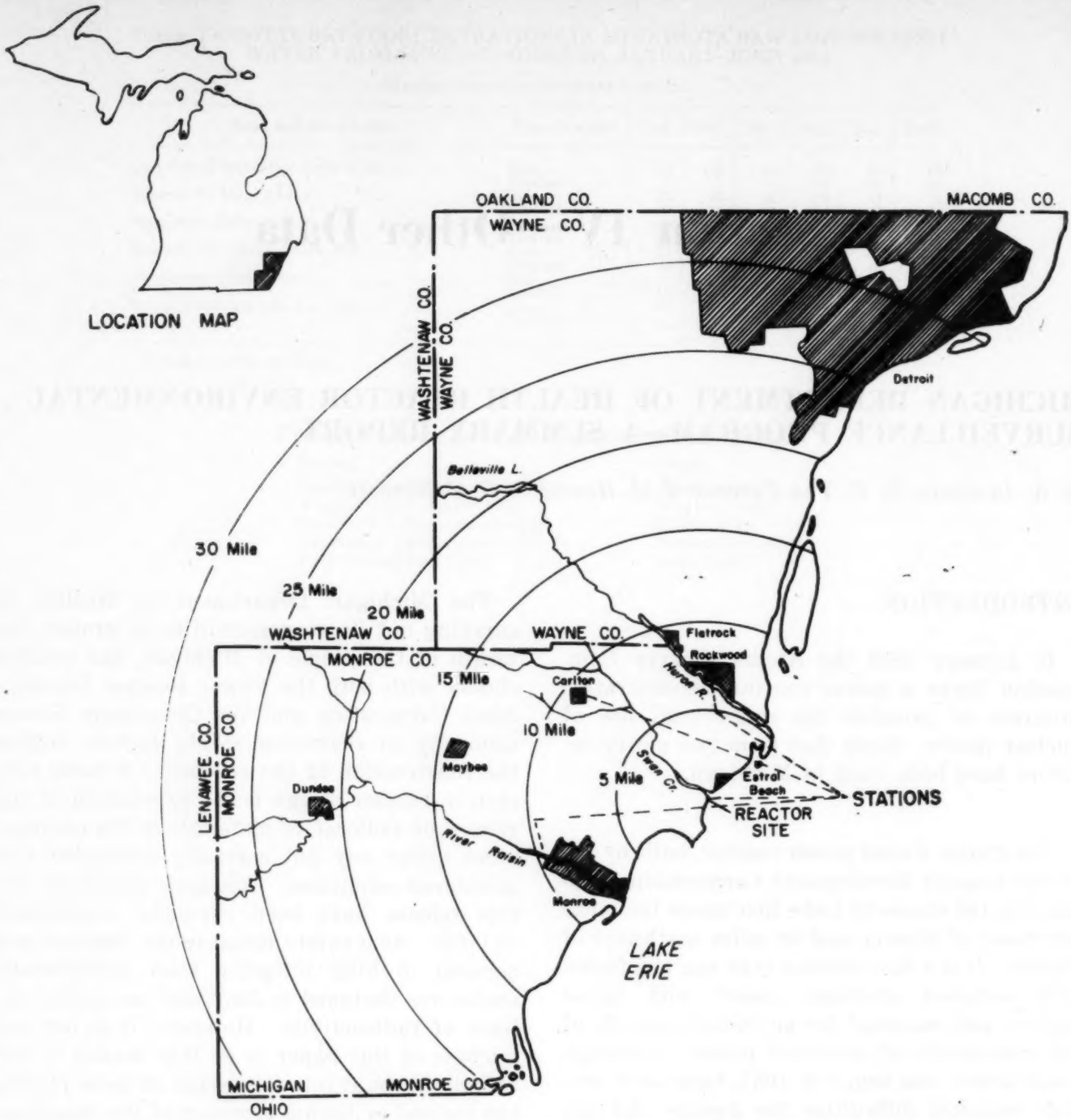

FIGURE 1.—ENRICO FERMI ATOMIC POWER PLANT, MONROE COUNTY, MICHIGAN, AIR SAMPLING STATION LOCATIONS

1. Establish pre-operational levels of radioactivity around the plant sites and populated areas from natural background and fallout.
2. Establish standard operating procedures for sampling, laboratory separations, and counting of samples to provide a basis for comparison of sample results with those of Enrico Fermi and Big Rock Point reactors, and other agencies.
3. Establish levels of radioactivity in three areas of the State so that abnormal trends can be detected in one particular area.
4. Protect the health of the workers at the reactor sites and the population at large by taking steps to minimize the hazards should environmental reconcentration of radioactive materials be detected or an accident occur.

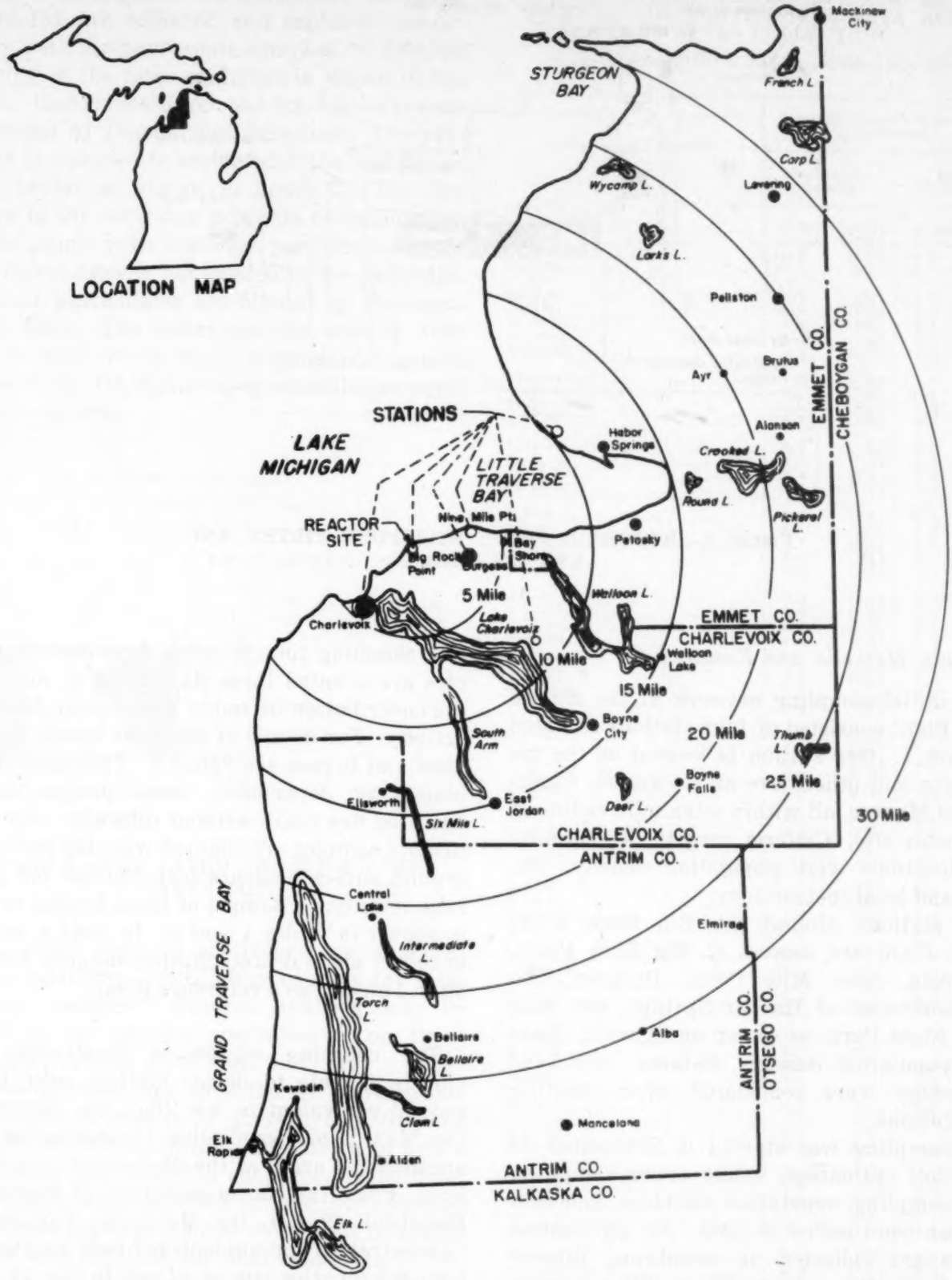

FIGURE 2.—BIG ROCK POINT ATOMIC POWER PLANT, CHARLEVOIX COUNTY, MICHIGAN, AIR SAMPLING STATION LOCATIONS

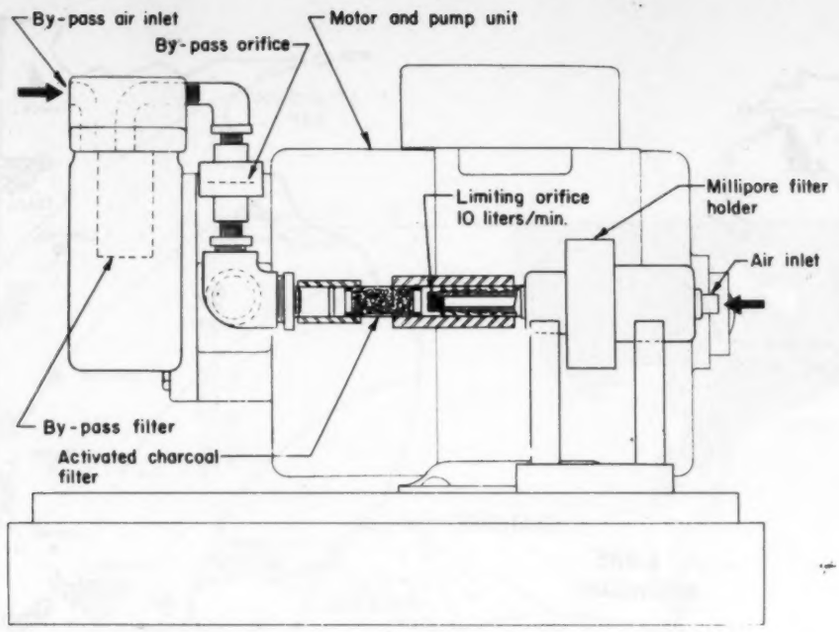

FIGURE 3.—MOTORAIR PUMP; MILLIPORE FILTER AND BY-PASS DETAIL

Materials, Methods, and Results

The initial sampling network at the Enrico Fermi Plant consisted of four stations as noted on figure 1. One station is located at the reactor site and others are at Rockwood, Carleton, and Monroe, all within a ten mile radius of the reactor site. Criteria used in determining these locations were population density, distance, and local meteorology.

The stations around the Big Rock Point Atomic Plant are located at Big Rock Point, Charlevoix, Nine Mile Point, Burgess, two miles northwest of Harbor Springs, and near Young State Park, as shown on figure 2. Here again population density, distance, and local meteorology were considered when locating these stations.

Air sampling was started in September of 1958. Soil evaluation, iodine vapor sampling, mouse sampling, vegetation sampling, and rain collection were added in 1959. Air particulate samples are collected on membrane filters.[1] Air is drawn through the filters with a suction pump[2] at the rate of 9 to 10.5 liters per minute. The sampling time is seven days and the samples are counted three days later to minimize the contribution of radon and thoron daughter activity. For details of the filter holder mechanism and bypass see figure 3. This system has been very dependable, some pumps having operated five years without difficulty. Air particulate samples are counted with the low background anti-coincidence beta counter for gross beta activity. A sample of some typical results is shown in tables 1 and 2. In 1961 a station to collect air and precipitation samples was set up in Lansing as a reference point.

The counting equipment mentioned previously is able to detect activity over background equivalent to less than ten percent of the Maximum Permissible Concentration for uncontrolled areas at the 95 percent confidence level. From the National Bureau of Standards Handbook 69 (*3*), the Maximum Permissible Concentration for unidentified beta emitters is 10^{-11} microcuries per cc of air in the vicinity of an atomic reactor (if there are no α emitters and if Pb^{210}, Ac^{227}, Ra^{228} and Pu^{241} are not present). The detection limit is then 10^{-12} microcuries per cc of air with the sampling system utilized.

[1] Type AA Millipore filters were used. Millipore Filter Corp., Bedford, Mass.

[2] Moto Air size CAC pumps are used. New Jersey Machine Corp., Hoboken, N.J. .

Activated charcoal cartridges for sampling iodine–131 are collected and replaced concurrently with air particulate samples. A detailed drawing of the filter cartridge is shown in figure 4. Cartridges developed by Sill (*4*) were assembled by Department personnel. The cartridge is inserted in series with the membrane filter holder as shown in figure 3. The fine screen in the cartridge prevents contamination of the pump with charcoal particles. An air particulate filter is not needed in the cartridge, since air particulates are filtered by the membrane filter. The cartridges are sized so that they fit, inlet side down, in a standard $3\frac{1}{32}$-inch diameter by $1\frac{1}{2}$ inches deep scintillation crystal for counting.

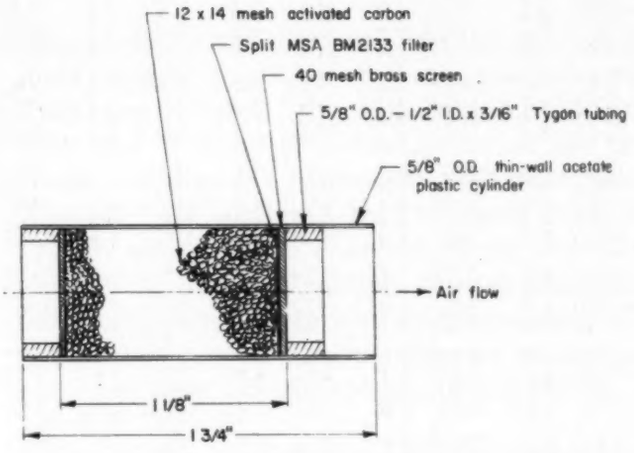
12 x 14 mesh activated carbon
Split MSA BM2133 filter
40 mesh brass screen
5/8" O.D. – 1/2" I.D. x 3/16" Tygon tubing
5/8" O.D. thin-wall acetate plastic cylinder
Air flow
1 1/8"
1 3/4"

FIGURE 4.—ACTIVATED CARBON FILTER CARTRIDGE

Activated charcoal cartridges are analyzed with a well type scintillation counter for total gamma radiation. Further analysis may be made by the gamma spectrometer on those samples showing significant activity.

Rain samples are collected in polyethylene containers by means of polyethylene funnels. Details for this apparatus are shown in figure 5. Samples are collected concurrently with air particulate samples. Each sample is evaporated by simmering to a volume which can be transferred to a planchet for final evaporation. Results are reported in microcuries per milliliter of sample and microcuries per square centimeter per day. Typical results are shown in tables 3 to 6.

Mice are caught around the reactor site sampling stations with common snap traps. Mice were chosen as a possible indicator of environ-

TABLE 1.—ENRICO FERMI REACTOR ENVIRONMENTAL AIR PARTICULATE BETA ACTIVITY THREE DAYS AFTER COLLECTION

[Limit of counting error at the 95% confidence level shown in parentheses]

Date End of Collection	Activity (pc/m³)—3 days after collection			
	Station 1L, Lansing		Station 4, Reactor Site	
9-5-61	0.049	(12%)	0.050	(12%)
9-11-61	0.048	(17%)	0.052	(14%)
9-18-61	10.4	(1%)	10.7	(1%)
9-25-61	17	(2%)	15	(2%)
10-2-61	4.3	(1%)	5.1	(1%)
10-9-61	6.9	(1%)	6.8	(1%)
10-16-61	4.4	(1%)	4.1	(1%)
10-23-61	4.5	(1%)	5.1	(1%)
10-30-61	5.4	(1%)	5.7	(1%)
11-6-61	1.2	(2%)	4.9	(1%)
11-13-61	9.1	(1%)	10.7	(1%)
11-20-61	4.4	(1%)	5.0	(1%)
11-27-61	6.7	(1%)	5.7	(1%)
12-4-61	6.6	(1%)	4.2	(1%)
12-11-61	4.4	(1%)	5.3	(1%)
12-18-61	2.4	(2%)	2.8	(2%)
12-26-61	5.4	(1%)	5.6	(1%)
1-2-62	2.9	(1%)	3.3	(1%)
1-8-62	4.1	(1%)	5.4	(1%)
1-15-62	5.7	(1%)	2.8	(3%)
1-22-62	7.9	(1%)	5.2	(1%)
1-29-62	5.5	(1%)	5.7	(1%)
2-5-62	3.9	(1%)	4.6	(1%)
2-12-62	4.9	(1%)	4.9	(1%)
2-19-62	5.7	(1%)	6.1	(1%)
2-26-62	4.4	(1%)	4.5	(1%)
3-5-62	5.1	(1%)	5.1	(1%)
3-12-62	3.9	(1%)	4.6	(1%)
3-19-62	3.5	(1%)	3.7	(1%)
3-26-62	6.9	(1%)	—	—
4-2-62	5.8	(1%)	5.0	(1%)
4-9-62	5.3	(1%)	5.2	(1%)
4-16-62	4.9	(1%)	4.5	(1%)
4-23-62	4.7	(1%)	5.2	(1%)
4-30-62	7.3	(1%)	6.8	(1%)
5-7-62	4.4	(1%)	4.1	(1%)
5-14-62	5.5	(1%)	4.6	(1%)
5-21-62	3.2	(2%)	5.2	(1%)
5-28-62	4.2	(1%)	4.2	(1%)
6-4-62	1.4	(2%)	2.5	(2%)
6-11-62	5.0	(1%)	4.0	(1%)
6-18-62	5.0	(1%)	6.3	(1%)
6-25-62	3.7	(1%)	3.9	(1%)
7-2-62	4.2	(2%)	4.4	(1%)
7-9-62	2.2	(2%)	3.4	(2%)
7-16-62	5.8	(1%)	4.1	(1%)
7-23-62	2.2	(2%)	2.5	(2%)
7-30-62	2.7	(1%)	2.7	(2%)
8-6-62	1.8	(2%)	1.7	(2%)
8-13-62	1.9	(2%)	—	—
8-20-62	2.0	(2%)	2.0	(2%)
8-27-62	1.7	(2%)	2.0	(2%)
9-4-62	1.7	(2%)	3.9	(1%)
9-10-62	5.0	(1%)	5.4	(2%)
9-17-62	2.7	(2%)	—	—
9-24-62	3.7	(1%)	3.8	(2%)
10-1-62	3.0	(2%)	2.4	(2%)
10-8-62	2.7	(2%)	4.9	(1%)
10-15-62	1.5	(3%)	2.9	(2%)
10-22-62	63	(2%)	7.7	(1%)
10-29-62	3.6	(1%)	3.4	(2%)
11-5-62	2.5	(2%)	2.6	(2%)
11-13-62	5.3	(1%)	8.9	(1%)
11-19-62	5.4	(1%)	10	(1%)
11-26-62	4.5	(1%)	8.1	(1%)
12-3-62	13	(1%)	32	(1%)
12-10-62	8.2	(1%)	4.3	(1%)
12-17-62	4.9	(1%)	4.0	(1%)
12-24-62	3.1	(2%)	5.9	(1%)
12-31-62	8.3	(1%)	—	—
1-7-63	2.6	(2%)	3.2	(2%)
1-14-63	4.2	(2%)	8.8	(1%)
1-21-63	9.3	(1%)	8.5	(2%)
1-28-63	6.3	(1%)	7.8	(1%)

TABLE 2.—BIG ROCK POINT REACTOR ENVIRONMENTAL AIR PARTICULATE BETA ACTIVITY THREE DAYS AFTER COLLECTION

[Limit of counting error at the 95% confidence level in parentheses]

Date end of collection	Activity (pc/m³)—3 days after collection											
	Station 1 Charlevoix		Station 2 Reactor Site		Station 3 Burgess		Station 4 9 Mile Point		Station 5 5 Mile Creek		Station 6 Oyster Bay	
9-9-61	0.050	(18%)	0.041	(16%)	0.040	(16%)	—	—	0.044	(18%)	0.033	(22%)
9-16-61	3.62	(1%)	2.68	(1%)	0.67	(4%)	3.97	(1%)	1.04	(3%)	0.30	(5%)
9-23-61	43.0	(3%)	41.0	(3%)	46.0	(3%)	33.0	(3%)	15.0	(5%)	40.0	(4%)
9-30-61	4.0	(1%)	4.8	(1%)	4.0	(1%)	4.0	(1%)	3.2	(1%)	3.7	(1%)
10-7-61	8.5	(1%)	6.7	(1%)	6.9	(1%)	5.8	(1%)	—	—	6.4	(1%)
10-14-61	4.5	(1%)	4.2	(1%)	4.9	(1%)	4.8	(1%)	5.3	(1%)	4.2	(1%)
10-21-61	5.6	(1%)	4.1	(1%)	6.3	(1%)	4.1	(1%)	5.3	(1%)	3.2	(2%)
10-28-61	4.1	(1%)	4.8	(1%)	5.5	(1%)	5.6	(1%)	4.1	(1%)	4.1	(1%)
11-4-61	6.5	(1%)	5.3	(1%)	6.6	(1%)	5.7	(1%)	7.2	(1%)	5.5	(1%)
11-11-61	7.8	(1%)	4.6	(1%)	9.3	(1%)	5.7	(1%)	6.1	(1%)	5.7	(1%)
11-18-61	13.1	(1%)	12.2	(1%)	13.6	(1%)	4.2	(1%)	11.6	(1%)	4.8	(1%)
11-25-61	6.1	(1%)	4.9	(1%)	5.6	(1%)	6.2	(1%)	5.2	(1%)	5.6	(1%)
12-2-61	4.7	(1%)	4.1	(1%)	4.4	(1%)	4.1	(1%)	5.7	(1%)	4.8	(1%)
12-9-61	5.4	(1%)	5.4	(1%)	6.6	(1%)	6.3	(1%)	5.7	(1%)	3.2	(1%)
12-16-61	2.7	(2%)	2.6	(2%)	2.7	(2%)	2.2	(2%)	3.0	(2%)	2.7	(2%)
12-23-61	4.3	(1%)	4.9	(1%)	4.2	(1%)	1.8	(2%)	4.5	(1%)	4.3	(1%)
12-30-61	4.4	(1%)	4.7	(1%)	4.2	(1%)	5.1	(1%)	4.4	(1%)	3.5	(1%)
1-6-62	7.2	(1%)	8.0	(1%)	6.7	(1%)	7.0	(1%)	6.7	(1%)	5.9	(1%)
1-13-62	7.6	(1%)	7.4	(1%)	8.6	(1%)	7.7	(1%)	9.0	(1%)	7.8	(1%)
1-20-62	7.0	(1%)	—	—	7.2	(1%)	7.1	(1%)	7.7	(1%)	7.0	(1%)
1-27-62	6.9	(1%)	6.9	(1%)	6.6	(1%)	7.4	(1%)	7.9	(1%)	6.6	(1%)
2-3-62	4.0	(1%)	4.8	(1%)	4.3	(1%)	5.1	(1%)	5.2	(1%)	5.0	(1%)
2-10-62	4.1	(1%)	4.8	(1%)	4.7	(1%)	4.1	(1%)	4.3	(1%)	4.9	(1%)
2-17-62	8.1	(1%)	9.1	(1%)	7.8	(1%)	8.4	(1%)	7.9	(1%)	8.7	(1%)
2-24-62	5.4	(1%)	5.3	(1%)	5.4	(1%)	5.1	(1%)	5.1	(1%)	5.2	(1%)
3-3-62	5.3	(1%)	5.7	(1%)	5.6	(1%)	6.2	(1%)	5.6	(1%)	5.7	(1%)
3-10-62	5.6	(1%)	5.4	(1%)	5.5	(1%)	5.8	(1%)	5.7	(1%)	5.6	(1%)
3-17-62	4.4	(1%)	4.4	(1%)	4.6	(1%)	4.4	(1%)	4.2	(1%)	4.2	(1%)
3-24-62	4.2	(1%)	4.4	(1%)	4.5	(1%)	4.4	(1%)	4.5	(1%)	4.8	(1%)
3-31-62	6.7	(1%)	6.9	(1%)	7.1	(1%)	6.0	(1%)	6.8	(1%)	6.8	(1%)
4-7-62	6.0	(1%)	6.3	(1%)	6.6	(1%)	7.2	(1%)	6.0	(1%)	6.1	(1%)
4-14-62	5.3	(1%)	4.8	(1%)	5.1	(1%)	4.8	(1%)	4.9	(1%)	5.2	(1%)
4-21-62	4.0	(1%)	4.0	(1%)	4.3	(1%)	3.9	(1%)	4.1	(1%)	4.2	(1%)
4-28-62	5.7	(1%)	5.5	(1%)	5.5	(1%)	5.1	(1%)	4.5	(1%)	5.7	(1%)
5-5-62	2.8	(3%)	3.0	(2%)	3.0	(2%)	2.6	(2%)	2.8	(2%)	3.1	(2%)
5-12-62	4.6	(1%)	5.2	(1%)	5.2	(1%)	5.4	(1%)	4.9	(1%)	4.6	(1%)
5-19-62	7.6	(1%)	6.0	(1%)	6.7	(1%)	5.6	(1%)	5.7	(1%)	6.4	(1%)
5-26-62	14	(1%)	5.1	(1%)	5.2	(1%)	4.8	(1%)	5.4	(1%)	4.6	(1%)
6-2-62	2.9	(2%)	2.7	(2%)	3.0	(2%)	2.9	(2%)	3.0	(2%)	2.7	(2%)
6-9-62	4.9	(1%)	5.4	(1%)	5.6	(1%)	5.4	(1%)	5.1	(1%)	5.2	(1%)
6-16-62	6.6	(1%)	6.0	(1%)	6.1	(1%)	5.5	(1%)	7.0	(1%)	6.0	(1%)
6-23-62	4.1	(1%)	3.7	(1%)	10	(1%)	3.9	(1%)	4.2	(1%)	4.2	(1%)
6-30-62	4.2	(2%)	4.4	(1%)	4.9	(1%)	4.7	(1%)	4.3	(1%)	4.9	(1%)
7-7-62	5.5	(1%)	5.2	(1%)	5.2	(1%)	5.4	(1%)	5.9	(1%)	5.1	(1%)
7-14-62	3.9	(1%)	4.1	(1%)	4.2	(1%)	4.1	(1%)	4.0	(1%)	3.9	(1%)
7-21-62	1.9	(2%)	2.1	(2%)	2.1	(2%)	1.5	(2%)	2.0	(2%)	2.1	(2%)
7-28-62	5.2	(1%)	2.5	(2%)	2.7	(2%)	2.6	(2%)	2.6	(2%)	2.5	(2%)
8-4-62	2.8	(2%)	2.7	(2%)	2.7	(2%)	2.8	(2%)	3.1	(2%)	2.6	(2%)
8-11-62	2.1	(2%)	1.9	(2%)	1.9	(2%)	—	—	2.0	(2%)	1.7	(2%)
8-18-62	1.9	(2%)	2.1	(2%)	2.0	(2%)	1.9	(2%)	1.9	(2%)	2.0	(2%)
8-25-62	2.1	(2%)	2.2	(2%)	1.8	(2%)	1.8	(2%)	1.9	(2%)	1.8	(2%)
9-1-62	3.0	(2%)	3.3	(2%)	3.0	(2%)	2.1	(2%)	1.7	(2%)	2.8	(2%)
9-8-62	5.7	(1%)	9.5	(5%)	5.3	(6%)	2.2	(2%)	6.1	(1%)	5.8	(1%)
9-15-62	2.7	(2%)	2.7	(2%)	2.4	(2%)	—	—	3.5	(1%)	3.5	(1%)
9-24-62	6.6	(1%)	5.3	(1%)	4.7	(1%)	6.1	(1%)	4.5	(1%)	3.9	(1%)
9-29-62	3.0	(2%)	3.4	(1%)	2.6	(2%)	2.3	(2%)	2.1	(2%)	2.2	(2%)
10-6-62	5.2	(1%)	5.5	(1%)	5.0	(1%)	5.5	(1%)	5.6	(1%)	5.2	(1%)
10-13-62	2.1	(2%)	2.5	(2%)	2.6	(2%)	2.6	(2%)	2.2	(2%)	2.1	(2%)
10-20-62	3.6	(2%)	3.8	(1%)	4.3	(1%)	3.3	(2%)	4.2	(1%)	3.9	(1%)
10-27-62	4.1	(1%)	4.2	(1%)	3.7	(1%)	4.3	(1%)	4.2	(1%)	4.7	(1%)
11-5-62	3.3	(2%)	3.3	(2%)	7.1	(1%)	2.4	(2%)	4.2	(1%)	3.6	(1%)
11-10-62	4.5	(1%)	4.7	(1%)	3.2	(1%)	4.8	(1%)	3.7	(1%)	2.6	(1%)
11-17-62	8.2	(1%)	10	(1%)	7.8	(1%)	9.0	(1%)	8.0	(1%)	5.7	(1%)
11-24-62	4.9	(1%)	7.1	(1%)	5.9	(1%)	4.5	(1%)	4.5	(1%)	3.7	(1%)
12-1-62	22	(3%)	26	(3%)	21	(3%)	14	(1%)	19	(1%)	23	(3%)
12-8-62	9.4	(1%)	7.7	(1%)	7.8	(1%)	6.0	(1%)	5.4	(1%)	2.7	(2%)
12-15-62	4.0	(1%)	4.0	(1%)	4.2	(1%)	5.0	(1%)	4.1	(1%)	4.4	(1%)
12-22-62	6.1	(1%)	7.0	(1%)	5.2	(1%)	5.1	(1%)	5.7	(1%)	5.6	(1%)
12-29-62	6.9	(1%)	8.7	(1%)	7.1	(1%)	9.6	(1%)	6.9	(1%)	8.0	(1%)

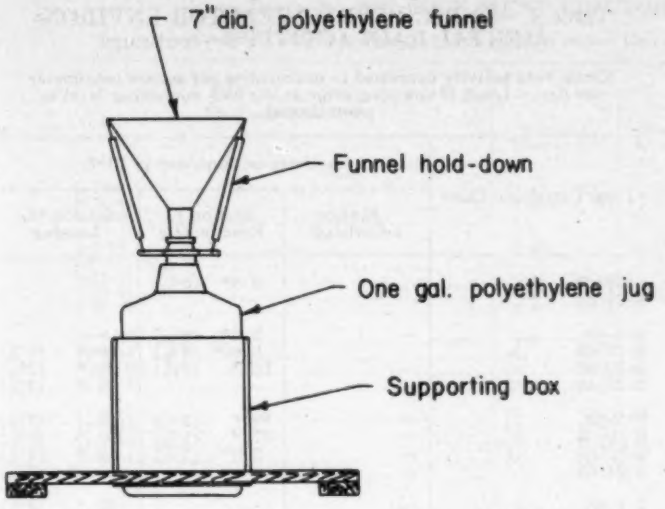

FIGURE 5.—RAIN SAMPLER

mental reconcentration and are the only mammals readily available at both reactor sites. They are weighed, the skin is removed, and after the thyroids have been removed the carcasses are digested in concentrated nitric acid. Thyroids are analyzed by the same counting system used for the charcoal filters described previously. A radioactive barium-strontium determination is performed on the carcass. The results are reported in microcuries of barium-stontium beta activity per gram of mouse, as noted in table 7.

Vegetation samples consisting of plants such as corn, soy beans, and grass are collected in the vicinity of each station on a weekly basis during the growing season. Gross beta activity is determined and reported as shown in tables 8 and 9. Barium-strontium and calcium determinations are also made.

Soil samples have been collected at monthly intervals from the vicinity of each station. Gross beta activity is determined for the acid-soluble portion as microcuries per gram of dry soil as shown in tables 10 and 11.

During the past year a 400-channel gamma spectrometer has been added to the laboratory equipment. Milk is now being collected on a weekly basis from dairy plants located in Charlevoix and Wyandotte, Michigan as well as dairies in five other localities in the state. Milk is checked for iodine–131, cesium–137, potassium–40, and barium-lanthanum–140 activity. An analysis for strontium–90 is also performed on selected samples.

TABLE 3.—ENRICO FERMI REACTOR ENVIRONMENTAL RAIN ACTIVITY

[Gross beta activity expressed in microcuries per milliliter. Limit of counting error at the 95% confidence level in parentheses]

Final Collection Date	Activity—pc/ml. (x 10^{-9})			
	Station 1L, Lansing		Station 4, Reactor Site	
8-7-61	1.1*	(13%)	0.86*	(17%)
8-14-61	Trace*		0.63*	(26%)
8-21-61	1.1*	(37%)	0.85*	(32%)
8-28-61	1.0*	(10%)	1.3*	(17%)
9-5-61	0.42*	(31%)	Trace*	
9-11-61	1.3*	(51%)	Trace*	
9-18-61	0.28*	(39%)	2.6*	(28%)
9-25-61	28.*	(3%)	6.9*	(5%)
10-2-61	50.*	(1%)	21.*	(6%)
10-9-61	—	—	—	—
10-16-61	41.*	(4%)	55.*	(6%)
10-23-61	—	—	37.*	(9%)
10-30-61	85.*	(1%)	250.*	(1%)
11-6-61	84.*	(3%)	274.*	(3%)
11-13-61	—	—	222.*	(4%)
11-20-61	59.*	(2%)	35.*	(2%)
11-27-61	100.*	(2%)	62.*	(3%)
12-4-61	—	—	260.*	(3%)
12-11-61	120.*	(2%)	89.*	(3%)
12-18-61	150.*	(2%)	110.*	(3%)
Rain Sampling discontinued during winter.				
3-12-62	—	—	50.*	(3%)
3-19-62	—	—	79.*	(3%)
3-26-62	51.*	(3%)	94.*	(3%)
4-2-62	180.*	(3%)	170.*	(8%)
4-9-62	15.*	(5%)	52.*	(4%)
4-16-62	30.*	(4%)	85.*	(5%)
4-23-62	240.*	(3%)	62.*	(4%)
4-30-62	190.*	(3%)	—	—
5-7-62	65.*	(1%)	71.*	(2%)
5-14-62	110.*	(5%)	—	—
5-21-62	—	—	150.*	(3%)
5-28-62	—	—	87.*	(4%)
6-4-62	240.*	(2%)	180.*	(1%)
6-11-62	40.*	(2%)	62.*	(3%)
6-18-62	32.*	(2%)	81.*	(3%)
6-25-62	88.*	(2%)	130.*	(2%)
7-2-62	—	—	—	—
7-9-62	8.5*	(4%)	30.*	(2%)
7-16-62	—	—	78.*	(2%)
7-23-62	50.*	(3%)	57.*	(2%)
7-30-62	64.*	(3%)	—	—
8-6-62	18.*	(3%)	—	—
8-13-62	49.*	(4%)	—	—
8-20-62	56.*	(4%)	35.*	(3%)
8-27-62	59.*	(3%)	33.*	(3%)
9-4-62	—	—	26.*	(4%)
9-10-62	30.*	(3%)	20.*	(3%)
9-17-62	42.*	(2%)	29.*	(2%)
9-24-62	150.*	(2%)	160.*	(2%)
10-1-62	—	—	48.*	(4%)
10-8-62	89.*	(2%)	60.*	(2%)
10-15-62	140.*	(4%)	400.*	(4%)
10-22-62	85.*	(2%)	78.*	(2%)
10-29-62	110.*	(2%)	—	—
11-5-62	130.*	(3%)	170.*	(2%)
11-13-62	58.*	(6%)	42.*	(2%)
11-19-62	190.*	(2%)	—	—
11-26-62	—	—	—	—
12-3-62	—	—	—	—
12-10-62	—	—	—	—
Discontinued rain sampling for winter.				

* Gross Beta Activity—No Barium-Strontium Separation
— No Sample Collected

The water pollution program is under the jurisdiction of the Michigan Water Resources Commission and a program of sampling surface water and biota around the reactor sites has been set up by that Commission. Sample results are readily available to this department as part of the general surveillance program.

A program of monitoring external gamma radiation at each station by the use of film badges has been initiated during the past year.

TABLE 4.—ENRICO FERMI REACTOR ENVIRONMENTAL RAIN ACTIVITY

[Gross beta activity expressed in microcuries per square centimeter per day. Limit of counting error at the 95% confidence level in parentheses]

Final Collection Date	Activity—μc/cm²/day (x 10⁻⁹)			
	Station 1L, Lansing		Station 4, Reactor Site	
8-21-61	0.11*	(37%)	0.14*	(32%)
8-28-61	0.64*	(10%)	0.35*	(17%)
9-5-61	0.15*	(31%)	Trace*	
9-11-61	0.07*	(51%)	Trace*	
9-18-61	0.10*	(39%)	0.16*	(28%)
9-25-61	9.7*	(3%)	3.2*	(5%)
10-2-61	40.*	(1%)	2.1*	(6%)
10-9-61	—	—	—	—
10-16-61	5.2*	(4%)	2.2*	(6%)
10-23-61	—	—	1.1*	(9%)
10-30-61	43.*	(1%)	44.*	(1%)
11-6-61	9.7*	(3%)	10.*	(3%)
11-13-61	—	—	5.4*	(4%)
11-20-61	30.*	(2%)	19.*	(2%)
11-27-61	19.*	(2%)	9.7*	(3%)
12-4-61	—	—	7.5*	(3%)
12-11-61	32.*	(2%)	11.*	(3%)
12-18-61**	30.*	(2%)	11.*	(3%)
3-12-62	—	—	6.7*	(3%)
3-19-62	—	—	8.3*	(3%)
3-26-62	9.6*	(3%)	6.7*	(3%)
4-2-62	4.2*	(3%)	1.4*	(8%)
4-9-62	1.7*	(5%)	6.0*	(4%)
4-16-62	4.6*	(4%)	3.2*	(5%)
4-23-62	9.2*	(3%)	4.3*	(4%)
4-30-62	8.9*	(3%)	—	—
5-7-62	49.*	(1%)	20.*	(2%)
5-14-62	3.1*	(5%)	—	—
5-21-62	—	—	11.*	(3%)
5-28-62	—	—	5.3*	(4%)
6-4-62	14.*	(2%)	40.*	(1%)
6-11-62	20.*	(2%)	6.2*	(3%)
6-18-62	14.*	(2%)	7.6*	(3%)
6-25-62	13.*	(2%)	25.*	(2%)
7-2-62	—	—	—	—
7-9-62	4.5*	(4%)	19.*	(2%)
7-16-62	—	—	21.*	(2%)
7-23-62	11.*	(3%)	29.*	(2%)
7-30-62	6.2*	(3%)	—	—
8-6-62	3.2*	(3%)	—	—
8-13-62	5.4*	(4%)	—	—
8-20-62	5.4*	(4%)	6.3*	(3%)
8-27-62	9.1*	(3%)	12.*	(3%)
9-4-62	—	—	4.1*	(4%)
9-10-62	7.9*	(3%)	6.2*	(3%)
9-17-62	14.*	(2%)	16.*	(2%)
9-24-62	16.*	(2%)	13.*	(2%)
10-1-62	—	—	5.6*	(4%)
10-8-62	23.*	(2%)	26.*	(2%)
10-15-62	5.1*	(4%)	5.6*	(4%)
10-22-62	28.*	(2%)	19.*	(2%)
10-29-62	12.*	(2%)	—	—
11-5-62	11.*	(3%)	27.*	(2%)
11-13-62	2.3*	(6%)	14.*	(2%)
11-19-62	23.*	(2%)	—	—
11-26-62	—	—	—	—
12-3-62	—	—	—	—
12-10-62**	—	—	—	—

Table 4.—ENRICO FERMI REACTOR ENVIRONMENTAL RAIN ACTIVITY—continued

[Gross beta activity expressed in microcuries per square centimeter per day. Limit of counting error at the 95% confidence level in parentheses]

Final Collection Date	Activity μc/cm²/day (x 10⁻⁹)					
	Station 1-Carleton		Station 4, Reactor Site		Station 1L, Lansing	
4-22-63	—		9.8*	(3%)	—	
4-29-63	—		—		—	
5-6-63	—		2.0*	(6%)	—	
5-13-63	—		0.90*	(9%)	82.*	(1%)
5-20-63	—		16.*	(2%)	22.*	(2%)
5-27-63	—		—		15.*	(2%)
6-3-63	—		19.*	(2%)	25.*	(2%)
6-10-63	—		37.*	(1%)	200.*	(1%)
6-17-63	—		3.0*	(5%)	12.*	(2%)
6-24-63	—		—		9.0*	(3%)
7-1-63	—		—		26.*	(2%)
7-9-63	—				3.0*	(5%)
7-15-63	0.55*	(12%)	1.1*	(8%)	32.*	(1%)
7-22-63	2.2*	(6%)	1.7*	(7%)	49.*	(1%)
7-29-63	2.4*	(5%)	4.2*	(4%)	—	—
8-5-63	3.4*	(5%)	3.5*	(5%)	54.*	(1%)
8-12-63	1.1*	(8%)	—	—	32.*	(1%)

* Gross Beta Activity—No Barium-Strontium Separation.
—No Sample Collected.
** Rain sampling discontinued for winter after this date.
Trace—Net cpm equal to or less than background.

Discussion

From the data obtained it is evident that the air sample results are quite consistent at Monroe, Lansing, and Charlevoix. Thus it is assumed that the data clearly indicate fluctuations due to fallout and natural activity. Should there be a rise in one particular part of the state, it would be quite easily detected. The same is true for individual stations around the reactor site. No significant activity in mice thyroids has been demonstrated to date. (Thus it would appear that milk is a more suitable indicator for iodine in the environment.)

It should be pointed out that there is no such thing as an absolute monitoring system. Unless sampling stations were prohibitively close together, a radioactive plume could pass between two stations with neither station showing activity. Under looping conditions a radioactive cloud could skip over a station. Under lofting conditions a radioactive cloud could remain above the station, yet drop down and touch earth directly behind it. Nevertheless, the monitoring of the Michigan Department of Health, which has been in operation about five years, has satisfied the objectives. Future needs will dictate any changes that may be necessary after reactors have been in operation for some time.

TABLE 5.—BIG ROCK POINT REACTOR ENVIRONMENTAL RAIN ACTIVITY

[Gross beta activity expressed as microcuries per milliter limit of counting error at the 95% confidence level in parentheses]

Final collection date	Activity—μc/ml (x 10^{-9})											
	Station 1 Charlevoix		Station 2 Reactor Site		Station 3 Burgess		Station 4 9 Mile Point		Station 5 5 Mile Creek		Station 6 Oyster Bay	
8-12-61	0.40	(39%)	1.6	(29%)	0.57	(40%)	1.2	(26%)	2.3	(33%)	0.77	(33%)
8-19-61	Trace		1.1		1.1		Trace		7.0		Trace	
8-26-61	—		—		—		—		—		—	
9-2-61	Trace		0.73	(24%)	0.34	(34%)	0.50	(30%)	.22	(40%)	Trace	
9-9-61	—		—		—		—		—		—	
9-16-61	0.44	(11%)	.66	(9%)	.41	(11%)	1.1	(7%)	.83	(8%)	0.70	(8%)
9-23-61	7.2	(5%)	8.6	(5%)	11.3	(4%)	14.6	(4%)	22.6	(3%)	15.9	(3%)
9-30-61	5.6	(6%)	19	(4%)	11	(4%)	18	(3%)	10	(5%)	12	(4%)
10-7-61	9.3	(5%)	19	(4%)	12	(5%)	18	(5%)	24	(3%)	10	(8%)
10-14-61	49	(4%)	42	(4%)	25	(5%)	75	(3%)	102	(3%)	52	(3%)
10-21-61	54	(5%)	88	(4%)	41	(3%)	62	(3%)	78	(2%)	115	(2%)
10-28-61	22	(4%)	68	(2%)	24	(4%)	52	(3%)	54	(2%)	28	(3%)
11-6-61	20	(3%)	36	(2%)	24	(2%)	35	(2%)	38	(2%)	39	(2%)
11-11-61	35	(4%)	44	(5%)	27	(4%)	50	(4%)	60	(4%)	29	(4%)
11-18-61	270	(1%)	140	(1%)	93	(1%)	150	(1%)	150	(1%)	28	(3%)
11-25-61	38	(4%)	150	(2%)	100	(2%)	79	(3%)	160	(2%)	85	(2%)
	Discontinued rain sampling for winter.											
4-28-62	81.0	(2%)	34.0	(3%)	1.0	(19%)	54.5	(2%)	64.0	(2%)	73.6	(2%)
5-5-62	16.0	(3%)	8.1	(4%)	33.0	(2%)	32.0	(2%)	41.0	(2%)	28.0	(2%)
5-12-62	90.0	(3%)	92.0	(4%)	140.0	(4%)	87.0	(5%)	72.0	(4%)	110.0	(4%)
5-14-62	40.0	(3%)	30.0	(4%)	58.0	(3%)	43.0	(3%)	48.0	(5%)	62.0	(2%)
5-26-62	100.0	(3%)	14.0	(7%)	82.0	(4%)	38.0	(4%)	60.0	(4%)	17.0	(5%)
6-2-62	98.0	(4%)	58.0	(5%)	110.0	(2%)	21.0	(5%)	100.0	(3%)	41.0	(5%)
6-9-62	—		—		—		—		—		—	
6-16-62	4.1	(9%)	39.0	(3%)	12.0	(4%)	33.0	(2%)	10.0	(5%)	44.0	(2%)
6-23-62	42.0	(3%)	42.0	(3%)	31.0	(3%)	100.0	(2%)	44.0	(3%)	23.0	(3%)
6-30-62	38.0	(3%)	130.0	(2%)	52.0	(3%)	68.0	(4%)	320.0	(1%)	88.0	(2%)

TABLE 6.—BIG ROCK POINT REACTOR ENVIRONMENTAL RAIN ACTIVITY

[Gross beta activity expressed as microcuries per square centimeter per day limit of counting error at the 95% confidence level in parentheses]

Final collection date	Activity—μc/cm²/day (x 10^{-9})											
	Station 1 Charlevoix		Station 2 Reactor Site		Station 3 Burgess		Station 4 9 Mile Point		Station 5 5 Mile Creek		Station 6 Oyster Bay	
8-12-61	0.10	(39%)	0.16	(29%)	0.10	(40%)	0.18	(26%)	0.13	(33%)	0.13	(33%)
8-19-61	Trace		0.10	(39%)	0.11	(37%)	Trace		0.40	(15%)	Trace	
8-26-61	—	—	—	—	—	—	—	—	—	—	—	—
9-2-61	Trace		0.20	(24%)	0.13	(34%)	0.15	(30%)	0.10	(40%)	Trace	
9-9-61	—	—	—	—	—	—	—	—	—	—	—	—
9-16-61	0.61	(11%)	0.92	(9%)	0.65	(11%)	1.8	(7%)	1.2	(8%)	1.1	(8%)
9-23-61	3.0	(5%)	3.0	(5%)	5.3	(4%)	5.8	(4%)	11.0	(3%)	8.0	(3%)
9-30-61	2.0	(6%)	5.0	(4%)	4.8	(4%)	6.4	(3%)	3.1	(5%)	4.5	(4%)
10-7-61	3.6	(5%)	5.0	(4%)	3.7	(5%)	3.6	(5%)	9.4	(3%)	1.4	(8%)
10-14-61	5.6	(4%)	5.6	(4%)	3.0	(5%)	7.8	(3%)	11	(3%)	10	(3%)
10-21-61	3.4	(5%)	20	(4%)	8.4	(3%)	9.3	(3%)	14	(2%)	22	(2%)
10-28-61	5.4	(4%)	14	(2%)	6.0	(4%)	12	(3%)	13	(2%)	7.6	(3%)
11-4-61	8.9	(3%)	15	(2%)	13	(2%)	15	(2%)	18	(2%)	19	(2%)
11-11-61	4.0	(4%)	3.5	(5%)	4.4	(4%)	5.2	(4%)	5.9	(4%)	5.7	(4%)
11-18-61	54	(1%)	45	(1%)	38	(1%)	42	(1%)	48	(1%)	8.7	(3%)
11-25-61	4.2	(4%)	17	(2%)	13	(2%)	8.6	(3%)	16	(2%)	13	(2%)
	Discontinued rain sampling for winter.											
4-28-62	21	(2%)	10	(3%)	.28	(19%)	16	(2%)	18	(2%)	27	(2%)
5-5-62	8.2	(3%)	3.9	(4%)	17	(2%)	14	(2%)	16	(2%)	17	(2%)
5-12-62	11	(3%)	4.8	(4%)	5.9	(4%)	3.7	(5%)	5.5	(4%)	6.0	(4%)
5-19-62	9.0	(3%)	5.6	(4%)	11	(3%)	7.4	(3%)	10	(3%)	14	(2%)
5-26-62	9.3	(3%)	1.7	(7%)	9.8	(3%)	4.0	(4%)	5.8	(4%)	2.9	(5%)
6-2-62	5.7	(4%)	3.7	(5%)	12	(2%)	3.1	(5%)	6.7	(3%)	3.8	(5%)
6-9-62	—	—	—	—	—	—	—	—	—	—	—	—
6-16-62	1.1	(9%)	11	(3%)	3.9	(4%)	14	(2%)	3.0	(5%)	13	(2%)
6-23-62	8.5	(3%)	7.9	(3%)	6.8	(3%)	20	(2%)	8.8	(3%)	7.0	(3%)
6-30-62	8.0	(3%)	19	(2%)	7.3	(3%)	5.9	(3%)	40	(1%)	13	(2%)
7-7-62	—	—	—	—	—	—	—	—	—	—	—	—
7-14-62	—	—	—	—	—	—	—	—	—	—	—	—
7-21-62	21	(2%)	42	(1%)	17	(2%)	12	(3%)	20	(2%)	13	(2%)
7-28-62	5.7	(4%)	1.9	(6%)	4.6	(4%)	5.8	(4%)	5.4	(4%)	3.4	(5%)
8-4-62	2.8	(5%)	3.8	(5%)	2.3	(6%)	2.8	(5%)	3.2	(5%)	3.0	(5%)
8-11-62	3.3	(5%)	2.5	(6%)	3.6	(5%)	2.3	(6%)	3.1	(5%)	2.9	(5%)
8-18-62	4.1	(4%)	5.7	(4%)	5.5	(4%)	5.2	(4%)	5.6	(4%)	4.1	(4%)
8-25-62	4.8	(4%)	5.9	(4%)	5.3	(4%)	5.4	(4%)	5.3	(4%)	7.5	(3%)
9-1-62	6.7	(3%)	8.7	(3%)	18	(2%)	6.4	(3%)	10	(3%)	4.8	(4%)
9-8-62	4.3	(4%)	13	(2%)	5.2	(4%)	4.4	(4%)	5.3	(4%)	5.2	(4%)
9-15-62	3.8	(5%)	8.0	(3%)	6.8	(3%)	5.5	(4%)	5.2	(4%)	8.1	(3%)
9-22-62	5.9	(4%)	11	(3%)	7.9	(3%)	8.0	(3%)	12	(2%)	15	(2%)
9-29-62	2.2	(6%)	3.3	(5%)	4.3	(4%)	6.4	(3%)	4.3	(4%)	8.4	(3%)
10-6-62	4.6	(4%)	5.4	(4%)	—	—	2.6	(5%)	2.6	(5%)	7.5	(3%)
10-13-62	—	—	—	—	3.3	(5%)	3.4	(5%)	—	—	6.0	(4%)
10-20-62	—	—	—	—	—	—	—	—	—	—	—	—
10-27-62	20	(2%)	23	(2%)	22	(2%)	21	(2%)	23	(2%)	29	(2%)
11-3-62	7.9	(3%)	7.3			(3%)	6.7	(3%)	9.6	(3%)	8.0	(3%)
11-10-62	4.8	(4%)	12	(3%)	78	(1%)	9.0	(3%)	9.4	(3%)	9.2	(3%)
11-17-62	—	—	—	—	—	—	—	—	—	—	—	—
11-24-62	18	(2%)	43	(1%)	5.6	(4%)	23	(2%)	13	(2%)	16	(2%)

TABLE 7.—BIG ROCK POINT REACTOR ENVIRONMENTAL BIOLOGICAL SAMPLES

[Barium-strontium beta activity in microcuries per gram of mouse. Limit of counting error at the 95% confidence level in parentheses]

Final collection date	Activity—μc/gm (x 10^{-7})					
	Station 1 Charlevoix	Station 2 Reactor Site	Station 3 Burgess	Station 4 9 Mile Point	Station 5 5 Mile Creek	Station 6 Oyster Bay
6-24-61	— —	1.1 (30%)	— —	— —	— —	— —
7-1-61	— —	.67 (35%)	— —	Trace	— —	— —
7-8-61	— —	1.0 (17%)	— —	Trace	— —	— —
7-29-61	— —	1.5 (15%)	— —	.38 (35%)	— —	— —
8-5-61	— —	.86 (25%)	— —	1.2 (22%)	— —	— —
8-12-61	— —	—	— —	Trace	— —	— —
8-19-61	— —	1.8 (22%)	Trace	—	1.2 (35%)	— —
8-26-61	— —	Trace	—	1.5 (22%)	1.4 (15%)	— —
9-9-61	— —	— —	—	1.0 (25%)	— —	— —
9-16-61	— —	Trace	—	Trace	— —	— —
9-23-61	— —	2.1 (32%)	1.7 (37%)	1.1 (30%)	— —	— —
9-30-61	— —	Trace	—	1.8 (15%)	.82 (27%)	— —
10-7-61	— —	3.8 (22%)	—	.45 (35%)	1.4 (17%)	— —
10-14-61	— —	Trace	—	.53 (25%)	1.6 (15%)	— —
10-21-61	— —	1.8 (20%)	—	1.2 (20%)	— —	— —
10-28-61	— —	1.1 (30%)	—	1.0 (32%)	1.3 (20%)	— —
11-4-61	— —	1.1 (30%)	—	—	1.2 (15%)	— —
11-11-61	— —	1.5 (37%)	—	Trace	—	— —
11-18-61	— —	1.0 (25%)	—	1.5 (25%)	Trace	— —
11-25-61	— —	—	2.0 (22%)	2.2 (35%)	1.3 (30%)	— —

— No Sample Collected.
Trace Net cpm equal to or less than background.

TABLE 8.—ENRICO FERMI REACTOR ENVIRONMENTAL BIOLOGICAL SAMPLES, GROSS BETA AND BARIUM-STRONTIUM ACTIVITY IN GRASS AND SOYBEANS

Collection Date	Grass				Soybeans			
	Gross β Activity		BaSr Activity		Gross β Activity		BaSr Activity	
	pc/gm grass	pc/gm ash	pc/gm grass	pc/gm ash	pc/gm grass	pc/gm ash	pc/gm grass	pc/gm ash
6-26-61	10	160						
	12	230						
	13	170						
	9	140						
7-31-61	15	170	Trace	Trace				
	8	120	"	"				
	20	200	"	"				
	11	120	"	"				
8-21-61	20	180	.032	.17	12	61	.13	1.2
	22	190	.063	.35	15	74	.20	1.6
	19	140	.12	.63	8.8	43	.18	1.3
	11	120			10	40	.13	.96
9-18-61	24	200	Trace	Trace			Trace	Trace
	25	170					"	"
	14	120	Trace	Trace			"	"
	30	210	"	"			"	"
10-9-61	8.3	80	Trace	Trace				
	200	2100	.12	.97				
	15	120	Trace	Trace				
	8.4	130	"	"				
10-30-61	24	240	Trace	Trace				
	21	160	.20	1.4				
	19	180	.087	.50				
	22	230	.084	.56				
11-20-61	31	320						
	38	380						
	37	350						
	66	680						
6-18-62	67	410			73	800		
	45	310			43	260		
	55	340			32	330		
	53	310						

TABLE 9.—BIG ROCK POINT REACTOR ENVIRONMENTAL BIOLOGICAL SAMPLES, GROSS BETA, BARIUM-STRONTIUM AND STRONTIUM-90 ACTIVITY IN GRASS

Final Collection Date	Gross β Activity		Barium-Strontium Activity		Strontium-90	
	pc/gm grass	pc/gm ash	pc/gm grass	pc/gm ash	pc/gm ash	pc/gm plant
7-1-61	22	180	Trace	Trace		
	14	200	"	"		
	15	190	"	"		
	14	170	"	"		
	11	160	"	"		
	11	140	"	"		
7-29-61	19	160	Trace	Trace		
	11	190	"	"		
	13	210	"	"		
	13	230	"	"		
	19	200	"	"		
	13	230	"	"		
9-2-61	5.9	190				
	7.8	250				
	21	85				
	21	180				
	15	170				
	12	170	----	----	10	0.6
9-30-61	37	460				
	17	460				
	29	290				
	32	360				
	37	270				
	30	280	----	----	7	0.6
10-28-61	200	2200				
	140	2700				
	180	1200				
	240	1600	----	----	4	0.4
	160	1300				
	180	1500				
11-25-61	230	5100	----	----	19	1.5
	220	4200	----	----	15	1.2
	270	3000	----	----	12	1.3
	300	2300	----	----	8	0.7
	280	3200				
	210	4500	----	----	19	1.2
6-6-62	----	----	----	----	18	1.2
					18	1.3
					22	1.1
7-14-62	----	----	----	----	26	0.9
					15	0.8
					24	1.2
					22	1.1
					29	1.5
8-11-62	----	----	----	----	34	1.7
					10	0.8
					27	1.3
					65	2.3
					37	1.9
9-8-62	----	----	----	----	56	1.2
					9	0.9
					71	2.9
					32	1.9

Summary

The Michigan Department of Health initiated an environmental surveillance program around the Enrico Fermi Power Reactor in 1958 and around the Big Rock Point Power Reactor in 1960. Environmental media sampled include air, rainwater, soil, field mice, and vegetation. Milk samples are collected from seven dairy plans around the State on a weekly basis. Two of the plants service the milksheds around Monroe and Charlevoix.

The initial program included four stations at the Enrico Fermi Power Reactor site and six stations around the Big Rock Point Reactor site as well as a station in Lansing. The results have demonstrated that the levels of radioactivity in media sampled since both plants became operational reflect only fluctuations in background radiation due to fallout and natural activity. Results are comparable in all three areas of the state. In the past 5 years, the program has satisfied its original objectives.

REFERENCES

(1) Big Rock Point Nuclear Plant: *Final Hazards Summary Report, Vol. 1*, Section 9.1–9.3.2.5, November 14, 1961, Consumers Power Company.

(2) Enrico Fermi Atomic Power Plant: *Technical Information and Hazards Summary Report, Vol. 3*, pp 113.1–113.15. Power Reactor Development Company.

(3) National Committee on Radiation Protection and Measurements: *Maximum Permissible Body Burdens and Maximum Permissible Concentration of Radionuclides in Air and Water for Occupational Exposure, National Bureau of Standards Handbook 69*, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (June 5, 1959).

(4) Sill, C. W. and J. K. Flygate: Iodine Monitoring at the National Reactor Testing Station, *Health Physics*, 2.261–268 (1960).

TABLE 10.—ENRICO FERMI ENVIRONMENTAL SOIL ACTIVITY, GROSS ACID SOLUBLE BETA ACTIVITY IN MICROCURIES PER GRAM OF DRY SOIL

[Limit of counting error at the 95% confidence level in parentheses]

Final collection date	Activity—μc/g (x10⁻⁶)			
	Station 1 Carleton	Station 2 Monroe	Station 3 Rockwood	Station 4 Reactor Site
5-18-59	2.5 (8%)	3.4 (6%)	3.3 (6%)	7.5 (4%)
6-8-59	4.4 (6%)	4.7 (5%)	2.8 (7%)	2.0 (8%)
8-24-59	1.0 (12%)	2.9 (7%)	2.6 (7%)	1.4 (10%)
9-21-59	3.4 (6%)	2.1 (8%)	1.4 (11%)	1.9 (9%)
10-27-59	7.7 (4%)	2.0 (8%)	2.5 (7%)	2.6 (7%)
11-23-59	1.5 (10%)	2.8 (7%)	2.7 (7%)	1.6 (10%)
1-11-60	2.1 (9%)	2.3 (8%)	1.9 (9%)	2.5 (8%)
2-8-60	3.0 (7%)	1.8 (9%)	3.3 (6%)	2.8 (7%)
3-14-60	1.4 (11%)	1.1 (12%)	0.91 (13%)	0.49 (19%)
4-4-60	1.9 (9%)	1.7 (9%)	2.3 (8%)	2.7 (7%)
5-16-60	1.5 (10%)	1.7 (9%)	1.7 (9%)	2.2 (8%)
6-20-60	1.3 (10%)	2.4 (7%)	2.4 (7%)	1.7 (9%)
7-25-60	1.5 (10%)	1.9 (9%)	1.2 (11%)	1.9 (9%)
8-15-60	1.1 (8%)	2.4 (6%)	1.4 (7%)	1.7 (7%)
9-19-60	1.3 (8%)	1.7 (7%)	1.2 (8%)	0.94 (9%)
10-24-60	1.5 (7%)	1.7 (7%)	1.1 (8%)	0.73 (11%)
11-21-60	1.2 (5%)	1.8 (6%)	1.4 (7%)	1.4 (7%)
12-12-60	1.3 (8%)	1.5 (7%)	1.3 (8%)	1.2 (8%)
1-16-61	1.0 (9%)	1.6 (7%)	1.4 (7%)	1.3 (8%)
6-26-61	1.7 (9%)	1.9 (9%)	2.5 (8%)	1.2 (11%)
7-31-61	1.2 (11%)	1.6 (9%)	1.8 (9%)	2.3 (8%)
8-21-61	1.4 (10%)	1.8 (9%)	2.2 (8%)	2.1 (8%)
9-18-61	1.6 (10%)	2.2 (8%)	3.4 (6%)	0.67 (16%)
10-9-61	1.4 (10%)	1.8 (9%)	3.2 (7%)	1.0 (12%)
10-30-61	1.3 (10%)	1.1 (12%)	2.3 (8%)	1.5 (10%)
11-20-61	1.7 (9%)	1.7 (9%)	1.5 (10%)	1.5 (10%)

TABLE 11.—BIG ROCK POINT REACTOR ENVIRONMENTAL SOIL ACTIVITY, GROSS ACID SOLUBLE BETA ACTIVITY EXPRESSED AS MICROCURIES PER GRAM OF DRY SOIL

[Limit of counting error at the 95% confidence level in parentheses]

Final date of collection	Activity —μc/gm (x10⁻⁶)			
	Station 1 Charlevoix	Station 2 Reactor Site	Station 3 Burgess	Station 4, 9 Mile Point
10-8-60	1.7 (11%)	1.5 (13%)	2.6 (12%)	1.8 (9%)
12-3-60	1.3 (9%)	0.96 (10%)	1.1 (7%)	1.7 (9%)

	Activity—μc/gm (x10⁻⁶)					
	Station 1 Charlevoix	Station 2 Reactor Site	Station 3 Burgess	Station 4 9 Mile Point	Station 5 5 Mile Creek	Station 6 Oyster Bay
7-1-61	0.63 (16%)	1.8 (9%)	2.3 (8%)	3.2 (7%)	1.6 (10%)	2.0 (8%)
7-29-61	1.2 (11%)	0.24 (32%)	0.77 (15%)	3.2 (7%)	2.1 (8%)	1.2 (11%)
9-2-61	2.3 (8%)	8.3 (4%)	2.1 (8%)	3.6 (6%)	2.8 (7%)	5.7 (5%)
9-30-61	2.4 (8%)	3.0 (7%)	1.8 (9%)	4.9 (5%)	2.1 (8%)	4.2 (6%)
10-28-61	1.7 (7%)	1.1 (10%)	2.2 (8%)	1.9 (8%)	2.0 (7%)	2.5 (6%)
11-25-61	2.6 (9%)	1.5 (12%)	2.1 (8%)	2.4 (9%)	2.7 (8%)	3.4 (7%)

ENVIRONMENTAL LEVELS OF RADIOACTIVITY AT ATOMIC ENERGY COMMISSION INSTALLATIONS

The U. S. Atomic Energy Commission receives from its contractors periodic reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant perimeter surveys are required.

Summaries of the environmental radioactivity data for 23 AEC installations have appeared periodically in *RHD* since November 1960. Following are reports for Oak Ridge Area and Hanford Atomic Products Operation.

Releases of radioactive materials from these installations for the periods covered in the reports below are governed by standards set forth in appropriate chapters of the AEC manual. The radioactivity concentration limits applicable to effluents released from AEC installations are identical to those published in the Federal Register (*1*).

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1. Hanford Atomic Products Operation[1] Calendar Year 1963

General Electric Company
Richland, Washington

An evaluation of results obtained from the Hanford environmental surveillance program for 1963 indicates that most of the environmental radiation exposure for the majority of persons in the neighborhood of the Hanford project was due to natural sources and worldwide fallout rather than to Hanford operations.

Of the low-level wastes released to the environment from the Hanford plants, neutron-induced radionuclides present in reactor cooling water discharged to the Columbia River continued to be the source of greatest potential exposure to the people in the environs. The primary mechanisms of exposure from this source are drinking water derived from the river and consumption of fish and waterfowl which inhabit the river.

The city of Richland started using the Columbia River as a source of sanitary water during 1963. In the 4 months following startup of the new plant in August, this source contributed a total exposure amounting to about 5 percent of the annual permissible limit for populations. The gastrointestinal tract is the limiting organ for the mixture of nuclides present in drinking water pumped from the Columbia River. In Pasco and Kennewick, which are further downriver, the estimated exposures from drinking water were respectively about 5 percent and 1 percent of the GI tract limit (population at large) for the full 12 months of 1963. The only persons who received radiation exposures attributable to Hanford that were greater than those resulting from the drinking water were the people that ate local fish or waterfowl or who regularly consumed produce from nearby farms irrigated with water pumped from the Columbia River below the reactors.

The highly unlikely, but conceivable, combination of circumstances that would result in the greatest exposure to an individual from the radionuclides released by the Hanford plants is postulated as; (1) the consumption of

[1] Summarized from Hanford Atomic Products Operation, *Evaluation of Radiological Conditions in the Vicinity of Hanford for 1963*, HW–80991, February 24, 1964.

some 200 meals of locally-caught fish during the year, (2) the consumption of meat, milk, fruit, and vegetables from irrigated farms of the Riverview district, and (3) the drinking of water from the Pasco system. An individual with such habits could conceivably take in enough radioactive material of Hanford origin (mostly P^{32}) to supply about 45 percent of the annual permissible amount. In this case the bone is the organ that is most restrictive. This same individual could also take in enough Sr^{90} of the world-wide fallout origin to equal about 5 percent of the permissible amount—more than twice that estimated for 1962. The exposures from nuclides of Hanford origin and from fallout are not additive in relation to limits, however, since the Radiation Protection Guides recommended by the Federal Radiation Council are not applicable to fallout from weapons tests.

The amount of I^{131} in the Hanford environs was substantially less than in the previous 2 years when extensive testing of weapons was in progress. Nevertheless, worldwide fallout continued to be the dominant source of the I^{131} found locally, except for the month of September when abnormally large amounts were released from one of the chemical separations plants. For the calendar year 1963, the I^{131} in milk from local farms could have resulted in radiation exposures to the thyroids of infants of approximately 10 percent of the Federal Radiation Council Radiation Protection Guide.

The Hanford project is located in a semiarid region of southeastern Washington having an average annual rainfall of about 7 inches. Natural vegetation in this section of the state is sparse and primarily suited for grazing, although large areas near the project perimeter have gradually been put under irrigation during the past few years. The plant site comprises an area of about 500 square miles. The Columbia River flows through the project and forms part of the eastern boundary. The meteorology of the region is typical of a desert area; frequent strong inversions occur at night and break during the day to provide unstable and turbulent conditions. Near the plant production sites the prevailing winds are from the northwest with strong drainage and cross winds causing distorted flow patterns.

The populated areas of primary interest near the plant perimeter are Richmond, Pasco, and Kennewick. Smaller communities in the vicinity are Benton City, West Richland, Mesa, and Othello. All together about 80,000 people live in the vicinity of the project. Protection of these people from undue radiation exposure attributable to Hanford sources is one of the attendant responsibilities in the operation of the Hanford facilities.

During the course of operating the nuclear reactors, fuel fabrication plants, chemical separation plants and research and development laboratories, various radioactive wastes are generated. High level wastes are concentrated and retained in storage within the project area. Controlled releases of low-level wastes, for which concentration and retention are not feasible, are made to the ground. The Hanford practices governing radioactive waste disposal are described in the Hearings on Industrial Radioactive Waste Disposal held by the Joint Congressional Committee on Atomic Energy in 1959.

The Atomic Energy Commission Manual Chapters (*3*), the recommendations of the National Committee on Radiation Protection and Measurement (NCRP) (*4*), the International Commission on Radiological Protection (ICRP) (*5*), the Federal Radiation Council (FRC) (*6*) and the results of Hanford research programs form the basis of radiation protection practices at Hanford. The recommendations of these organizations in the form of permissible rates of intake of specific nuclides and guides for radiation exposure constitute criteria against which radiation exposures estimated from measurements of the Hanford environmental surveillance program are compared. The results of this comparison indicate the effectiveness of Hanford waste control and radiation protection practices and point out any conditions requiring attention.

This report estimates the annual exposure received by the individuals who are expected to receive the greatest amount of radiation from environmental sources, and the exposure received by people who are more typical residents of this region. These exposures are compared with the recommendations of the NCRP and FRC. The NCRP recommendations, in the form of maximum permissible exposures for

individuals that are not employed in radiation work, are 1,500 mrems per year to the GI tract, 500 mrems per year to the total body, and 3,000 mrems to the thyroid. The limits for bone-seekers are calculated with reference to biological effects observed from deposition of radium and are most readily applied in the form of maximum permissible rates of intake (MPRI).[2] Similar evaluations for previous years have also been reported (*2,7,8*). The Radiation Protection Guides established by the FRC for individuals are 1,500 mrems per year to the thyroid, 1,500 mrems per year to the bone, and 50 mrems to the whole body. The Radiation Protection Guides for the "average of a suitable sample of an exposed population group" are one-third of those for individuals.

ENVIRONMENTAL CONDITIONS

A discussion and interpretation of the results of the various Hanford environmental sampling programs are presented in the following text and tables.

Radionuclides in the Columbia River

Hanford's eight production reactors are cooled with Columbia River water. This water goes through filtration processes and then passes once through the reactors as a coolant before being returned to the river. Stable elements present in the cooling water are transformed into radionuclides during passage through the reactors, and radioactive materials formed on the surfaces of the fuel elements and channels are washed away by the cooling water.

Many of the radionuclides formed in reactor cooling water are short-lived and decay rapidly after formation. In addition to radioactive decay, some portion of the radionuclides is removed from the water by sedimentation and uptake by aquatic organisms. The radionuclides in the river also include some contribution of "fallout" from weapons tests.

[2] The MPRI is taken as the maximum permissible concentration in water for a given radionuclide, as recommended by the NCRP for persons in the neighborhood of controlled areas, multiplied by the rate of water intake as defined for the standard man. This amounts to one-tenth of the MPC's for continuous exposure of occupational workers multiplied by 2200 cc per day, or by 800 liters per year in the case of annual estimates.

Samples of river water were obtained every 2 weeks from Vernita Ferry, Hanford Ferry, 300 Area, the inlet to the Pasco municipal water plant, and Vancouver. Some samples of river water were also collected at Richland, particularly during the latter part of the year when the new water plant was in operation. The average concentrations of radionuclides measured routinely at the four river sampling stations are shown in table 1.

TABLE 1.—ANNUAL AVERAGE CONCENTRATIONS OF SELECTED RADIONUCLIDES IN COLUMBIA RIVER WATER, 1963

[pc/liter]

Radionuclide	Hanford Ferry	Richland	Pasco	Vancouver
Total Beta	52,000	23,000	11,000	500
RE+Y [1]	1,800	640	440	—
Na^{24}	7,700	3,400	1,600	—
P^{32}	340	260	190	30
Cr^{51}	12,000	8,800	6,700	2,600
Mn^{56}	9,800	—	—	—
Cu^{64}	17,000	5,900	2,300	—
Zn^{65}	470	380	220	60
As^{76}	2,400	1,200	750	—
Sr^{90}	1	1	1	1
I^{131}	12	8	8	4
Np^{239}	3,300	2,100	1,600	—

[1] Rare earths plus yttrium.

The Hanford Ferry monitoring station is about 7 miles downstream from the closest production reactor and about 6 miles upstream from the point where the project boundary crosses the Columbia River. Studies of effluent distribution at the Hanford Ferry indicate nonuniformity which causes sample results to show higher concentrations of most radionuclides than the average of the cross section at this location. Measurements on a traverse across the river at Richland indicated a fairly uniform distribution of the longer-lived radiosotopes throughout the river at this point. At Pasco, the distribution of radiosotopes in the river is slightly nonuniform because of the entry of the Yakima River some 10 miles upstream.

Vancouver, about 260 miles from the reactors, is the farthest downstream location where river water is routinely sampled for Hanford's surveillance program. Further downstream the intrusion of sea water into the Columbia River complicates quantitative measurement of the radionuclides.

Radiation exposure that results from the drinking of water pumped from the river and sent through treatment plants is discussed in the next section of this report. There is no known instance of untreated river water being consumed routinely by humans. For comparative purposes, however, the relationship between the concentrations of radionuclides in the untreated Columbia River water and published values for maximum permissible concentrations in water is shown in table 2. In this case the comparison is with the MPC's listed in Column 2, Table II of Annex I of AEC Manual Chapter Appendix 0524 (*3*). For the most part these MPC's are equivalent to one-tenth of the most limiting values recommended by the NCRP (*4*) for occupational workers. The marked reduction in percent of MPC_w that occurs with distance downstream from the reactors results principally from radioactive decay of the shorter-lived nuclides.

TABLE 2.—RELATIONSHIP BETWEEN THE CONCENTRATIONS OF RADIONUCLIDES IN UNTREATED COLUMBIA RIVER WATER AND MAXIMUM PERMISSILBE CONCENTRATIONS

Sampling location	% of MPC [1]
Hanford	34
Richland	17
Pasco	12
Vancouver	2

[1] This is a summation of the percentages of MPC's contributed by the several individual radionuclides measured routinely in the river water. The MPC's used and the method of summation are taken from AEC Manual Chapter 0524 (3).

Radionuclides in Drinking Water

In the latter part of 1963, Richland started up a new water treatment plant that draws water from the Columbia River. Previously Richland obtained its water from wells, and Kennewick and Pasco (downstream from Richland) were the nearest cities to the Hanford reactors that used Columbia River water. Sanitary water was collected at the Richland and Pasco water treatment plants every 2 weeks and analyzed for the important radionuclides. Similar analyses were made on Kennewick water once each month. The results of the radioanalysis of water from these plants are summarized in table 3.

TABLE 3.—ANNUAL AVERAGE CONCENTRATION OF SELECTED RADIONUCLIDES MEASURED IN SANITARY WATER, 1963

[pc/liter]

Radionuclide	Richland [1]	Pasco	Kennewick
Total Beta	23,000	4,000	600
RE+Y [2]	90	50	10
Na^{24}	3,000	600	90
P^{32}	130	40	<10
Cr^{51}	14,000	5,400	2,500
Cu^{64}	3,000	400	90
Zn^{65}	80	90	<20
As^{76}	800	200	<60
Sr^{90}	2	1	<0.5
I^{131}	10	5	<3
Np^{239}	2,500	800	30

[1] Averages for Richland are based only on the last quarter of 1963 when the new water treatment plant was in full operation. These averages may change significantly when a full year's operation is used.
[2] Rare earths plus yttrium.

The concentrations of short-lived radionuclides in the water at the time it is consumed is less than shown in the table because there is a significant flow time between the water plant and most consumers. The flow time may vary from hours to day depending upon the location of the customer on the distribution system.

Table 4 shows the removal of several radionuclides by the water treatment at Pasco and Richland. These data include the radioactive decay of the short-lived radionuclides during travel through the water treatment plant.

TABLE 4.—DEPLETION OF RADIONUCLIDES FROM COLUMBIA RIVER WATER BY TREATMENT AT THE RICHLAND AND PASCO WATER PLANTS, 1963

Radionuclide	% Depletion	
	Pasco	Richland
RE+Y [1]	90	80
Cu^{64}	80	40
P^{32}	80	50
As^{76}	80	40
Na^{24}	60	15
Zn^{65}	60	80
Np^{239}	50	—
Cr^{51}	20	—

[1] Rare earths plus yttrium

The calculated annual average dose to the GI tract, total body and the percentage MPRI for bone from sustained consumption of sanitary water at the three cities is presented in table 5.

The thyroid dose shown in table 5 for Pasco residents includes an increment accrued from fission products released by an unusually severe failure of a fuel element in one of the reactors

TABLE 5.—CALCULATED ANNUAL DOSE FOR SELECTED ORGANS FROM ROUTINE INGESTION OF SANITARY WATER [1], 1963

Location	Total body mrem	GI tract mrem	Bone % MPRI	Thyroid (small child) mrem
Richland [2]	1	25	0.8	22
Pasco	1.5	20	0.9	40
Kennewick	<1	<5	<0.5	<20

[1] Here and elsewhere in this report where a dose from an ingested nuclide is expressed in mrem units, the determination is made from parameters used by the ICRP to translate dose rates into Maximum Permissible Concentrations for drinking water. In most cases the estimated annual intakes of individual radionuclides were multiplied by conversion factors derived from the ICRP parameters and published by Vennart, *et al.* (*9*).

The "standard man" (*5*) beverage intake of 1.2 liters per day was used in this calculation. This departure from the 2.2 liters per day (total liquid intake for the "standard man" including foods) used for similar calculations in the past more reasonably represents the average exposure from drinking water alone.

[2] The radiation dose shown in this table for Richland residents was all accrued during the last 4 months of 1963 subsequent to the change from wells to Columbia River water.

that occurred on May 12, 1963. Fuel element failures are not unusual but the quantities of fission products released to the river from them are ordinarily small. During 1963, only the one on May 12 released enough fission products to warrant special evaluation. For estimating thyroid dose, a small child was considered to have consumed 1 liter of water from the Pasco supply during the time when the maximum concentration of I^{131} was present. The resulting dose to the child's thyroid would have been approximately 8 mrems. This would have increased his dose from about 6 percent of the FRC Radiation Protection Guide for an exposed population group to about 8 percent. The dose to the GI tract, bone and total body from this incident was negligible (*10*).

The dose received by the GI tract of Pasco residents continued at about the same level as experienced in 1962. Treatment of the reactor cooling water for reduction of As^{76}, Np^{239}, and other nuclides was continued during 1963. This modification consisted mainly of increased addition of alum in the clarifying process which reduced the amount of parent materials from which As^{76} and Np^{239} are formed.

Radionuclides in Fish and Waterfowl

Fish and waterfowl that feed in the Columbia River downstream from the reactors acquire some radionuclides that enter the river with the reactor effluent water. Except for suckers, whitefish usually contain the greatest concentration of radioactive materials; P^{32} is the radionuclide of greatest significance. Seasonal variation is affected by the amount of P^{32} released from the reactors, the feeding habits and metabolism of the fish, and flow rate of the river which determines the effective dilution of the reactor effluent. The concentration of P^{32} in whitefish starts to decrease late in the year and, due to cold water and limited feeding, continues to decrease until spring. As the temperature of the river water rises in the spring, the fish eat larger quantities of food organisms that have accumulated P^{32} and this results in an increased deposition of P^{32} in the fish. The trend is reversed in mid-spring by the high flow rates of the Columbia which afford greater dilution of effluent and thus lower concentrations of P^{32} in the food organisms. As the high flows recede in early summer and water temperatures rise further, the P^{32} content in fish again increases and reaches a maximum in late fall. The average concentration of P^{32} in whitefish sampled downstream from the reactors during 1963 was 420 pc/g of flesh, and the sample with the highest concentration contained 2,800 pc/g. The annual average Zn^{65} concentration in whitefish was 38 pc/g of flesh and the maximum was 120 pc/g in samples collected at Ringold. If whitefish were eaten at the rate of one meal per week (about 25 lb/year), the intake in 1963 would have been approximately 4.8 μc of P^{32} and 0.43 μc of Zn^{65}. The resulting exposure would have been about 100 mrems to the GI tract, 40 mrems to the total body, and 30 percent of the MPRI for bone.

In order to determine the consumption of locally caught fish more accurately, a number of fishermen were asked to estimate the quantities and kinds of fish they ate each year. This survey was carried out by personnel of the State of Washington, Department of Game. The data obtained thus far show that the individuals who probably ingest the largest amounts of P^{32} are fishermen who claim to eat bass, crappie, perch, and catfish at a frequency of 3 to 5 times a week. This number of fish meals implies an annual consumption of about 90 lb (in contrast with the 25 lb of whitefish used as a reference amount in the preceding paragraph), but the average P^{32} content of the

species involved is lower than in the whitefish. An intake of 7 μc of P^{32} during 1963 is estimated for an individual that claimed to eat some 200 meals of fresh fish caught from the Burbank Area.

People who eat local fish ingest Zn^{65} along with the P^{32}. The exposure that results from the Zn^{65} is very small but because it is a gamma emitter, its presence in the body can be detected by whole body counting techniques. (Small amounts of P^{32} in the body cannot be measured accurately because P^{32} emits only beta particles.) A few fishermen have been counted in the Hanford Whole Body Counter and the amounts of Zn^{65} detected were much smaller than expected on the basis of their estimated fish consumption. Such results suggest that fishermen tend to over-estimate their fish consumption and, therefore, that calculations of P^{32} intake based on such estimates yield values that are substantially higher than actually occurred.

Migratory waterfowl, such as mallard ducks and Canada geese, that have utilized the Hanford section of the river may also contain P^{32} and Zn^{65}. Hunters from Washington contributed samples from 299 ducks bagged during the 1963 hunting season. Results of radioassay of these samples and of 186 ducks collected from swamps and ponds within the project boundaries showed that, of all the ducks contributed by hunters, only 22 contained concentrations of P^{32} greater than the detectable level of 50 pc/g of flesh (wet weight) and only one was greater than 500 pc/g (540 pc/g). About one-half of the ducks collected within the project boundary contained detectable amounts of P^{32}, and 37 of these ducks contained greater than 500 pc P^{32}/g. The maximum concentration found was 4,800 pc/g of flesh.

Radionuclides in Marine Organisms

Zn^{65} and P^{32} are the only radionuclides of reactor effluent origin found in sufficient abundance beyond the mouth of the Columbia River to be of radiological interest. Oysters have been found to contain higher concentrations of Zn^{65} than other common sea food organisms. The average concentrations in 26 samples (a total of 52 lb) of oysters taken periodically throughout the year were 80 pc Zn^{65}/g and 4 pc P^{32}/g. Consumption of oysters containing these concentrations of Zn^{65} and P^{32} at a sustained rate of one meal per week (½ lb) would lead to an annual exposure of about 9 mrems to the GI tract, 6 mrems to the total body, and less than 0.5/percent of the MPRI for bone.

Radionuclides in the Atmosphere

At Hanford, gaseous waste is released to the atmosphere through 200-foot high stacks after removal of some 99 percent of the radioactive materials present. These radioactive materials are primarily associated with process vessel off-gases from the chemical separations facilities. Under normal operating conditions, the ventilation air from laboratory and reactor buildings contains comparatively minor amounts of radioactive materials.

Iodine–131 is the radionuclide of principal interest in the separations facilties process off-gases. During 1963 the annual average emission rate of I^{131} from the separations plant stacks was 0.38 curie per day. Monitoring for other specific radioisotopes was discontinued in 1963 because previous measurements had shown insignificant emission rates. Gross beta measurements are now made continuously to detect any change in emission rates of these other radionuclides. The results for the past 3 years are summarized in table 6. The fission product recovery facilities operating at Hanford contributed negligible amounts of radionuclides to the environs during 1963. The average emission rate of Sr^{90} from such facilities was less than 0.0018 curie per day.

TABLE 6.—ANNUAL AVERAGE EMISSION RATES OF SELECTED RADIONUCLIDES FROM SEPARATIONS PLANT STACKS

[curies/day]

Radionuclide	1963	1962	1961
I^{131}	0.38	0.35	0.7
$Zr\text{-}Nb^{95}$	—	0.0024	0.005
Ru^{103}	—	0.0009	0.003
Ru^{106}	—	0.0036	0.005
Ce^{141}	—	0.0002	0.006
Ce^{144}	—	0.015	0.01
Filterable gross beta	0.013	—	—

Measurements of air-borne I^{131} were made routinely at several locations within the Hanford reservation and at several locations adjacent to the plant. Results for the past few years are summarized in table 7.

The four locations listed in table 7 lie within a 45-degree sector southeast to south of the separations centers.

TABLE 7.—AVERAGE IODINE-131 CONCENTRATIONS IN THE ATMOSPHERE

[pc/m³]

Location	Distance from separation stacks miles	1963	1962	1961	1960
Benton City	20	0.03	0.08	0.02	0.05
North Richland [1]	20	—	0.10	0.04	0.04
Richland	23	0.02	0.04	0.02	0.03
Pasco	32	0.02	0.08	0.04	0.02

[1] The North Richland sampling location was discontinued in October 1963. A new sampling location was installed at the Prosser Barricade which lies in the same direction from the separations areas but is about 6 miles closer.

The annual average I^{131} concentrations in air during 1963 returned to the levels observed in 1961 prior to resumption of nuclear testing by the USSR. The long-term average release closely approximated the restrictive local operation guides until early September when an unplanned release of I^{131} occurred from a chemical separations facility. Early recognition of the abnormal conditon and immediate action successfully retained a major portion of the I^{131} within the plant. The concentration of I^{131} measured in air about the plant perimeter increased temporarily, but this did not significantly affect the longer-range annual exposure from inspired air. Measurement of I^{131} in air at locations about the plant perimeter indicated the average concentration during 1963 was less than 0.05 pc/m³. If such a concentration were sustained in inspired air, the resulting annual dose to the thyroid of the "standard man" would be less than 1 mrem.

Radionuclides in Milk and Agricultural Produce

The radioactivity in locally grown agricultural produce can be influenced by deposition of air-borne radionuclides, or by irrigation with water containing reactor effluent radionuclides. Chemical separations facilities are generally considered to be the principal local source of air-borne radionuclides. Under certain conditions, ventilation stacks of the reactors or laboratory facilities could possibly become of some small interest. The closest farming area to the separations facilities is about 13 miles away, and under most meteorological conditions this distance affords adequate dilution before the radioactive effluents reach the farming areas.

Most of the irrigated farm land near the Hanford plant uses water from the Yakima River, or from the Columbia River above the project. However, the Ringold farms and the Riverview district west of Pasco, which are about 15 and 30 miles downstream from the reactors, respectively, take water from the Columbia River for irrigation. Some of the reactor effluent radionuclides can be traced through the irrigation water to milk and other farm products. The Ringold farms, approximately 13 miles east of the production areas, involve about 20 people working some 500 acres of land with fruit as their principal product. The Riverview farm area has about 30 families that raise fruit, vegetables, beef, and dairy herds. This area is located about 30 miles southeast of chemical separations plants. Another agricultural area near the project is Benton City, located on the Yakima River about 20 miles directly south of the separations facilities.

Surveillance of the milk available to people living near the Hanford plants included samples from local farms and dairies and samples of commercial supplies sold in local stores. The concentrations of radionuclides found in the milk sold by stores was similar to that reported by the U. S. Public Health Service and the Washington State Department of Health (*11*) Milk from farms irrigated with water pumped from the Columbia River downstream from the reactors contained P^{32} and Zn^{65} as well as the fission products of fallout origin.

The Sr^{90} concentration in milk known to be of local origin ranged from less than 2 to 21 pc/liter. Such values are similar to concentrations found in commercial milk produced in areas that could not be affected by the Hanford plants. The average concentration of Sr^{90} in milk produced in the Hanford environs during 1963 was about 13 pc/liter, which is among the lowest concentrations in the nation. A temporary increase in Sr^{90} was noted during the spring as a result of the seasonal influx of world-wide fallout. Concentrations of Sr^{89} and Cs^{137} in milk analyzed at Hanford were generally below the detection level of 4 pc Sr^{89}/liter. and 30 pc Cs^{137}/liter. World-wide fallout is the principal source of these radionuclides in milk.

Measurements for I^{131} were made on all milk samples collected in 1963. The results of these measurements indicate that during the early part of the year, I^{131} concentrations were well below 10 pc/liter, and were following a generally decreasing trend. The maximum concentration of iodine–131 found in milk during the first half of the year was 84 pc/liter on June 19, 1963. This maximum value occurred at the same time as the peak of the influx of worldwide fallout, but this was probably a concidence. However, releases of iodine–131 from Hanford facilities were not sufficient to account for the observed levels in milk at this time. Following this peak, concentrations declined rapidly to 10 pc/liter or less.

In early September, I^{131} concentrations in milk again increased as a result of the inadvertent release of I^{131} from a separations plant previously described. The milk sampling program was increased in September and October and the maximum concentration actually measured was 140 pc I^{131}/liter in a sample collected in the West Richland-Benton City area. It was estimated that the highest thyroid dose resulting from the I^{131} release was probably received by a small child residing at the farm where the maximum milk results were obtained. By assuming a 4-gram thyroid for a 4-year old child and consumption of 1 liter of milk per day produced at the farm, it was estimated that the maximum thyroid dose during the 3-month period following the incident did not exceed 30 mrems. A whole body counter measurement of this child's thyroid in October 1963 confirmed the estimated thyroid burden of I^{131}. The value of 30 mrems can be compared with the FRC Radiation Protection Guide for individuals of 1,500 mrems per year.

Columbia River water removed below the reactors for irrigation is a source of P^{32} and Zn^{65} in milk at dairy farms in the Riverview and Ringold areas. The average concentrations of Zn^{65} in milk from the Riverview-Ringold area during 1963 was about 600 pc/liter and the concentration of P^{32} was about 800 pc/liter Zn^{65} or P^{32} are usually not detected in milk that is distributed through commercial outlets in the Tri-City area because such milk is not usually obtained from areas irrigated with water obtained from the Columbia River below the reactors.

At a consumption rate of 1 liter of milk per day the "fallout" radionuclides would contribute an average annual dose of less than 1 mrem to the GI tract, about 8 mrems to the total body, and about 7 percent of the FRC rate of intake guide for bone.[3] Those residents who drink milk obtained locally from the Ringold and Riverview areas would receive some additional exposure from P^{32} and Zn^{65} amounting to about 8 mrems to the GI tract, 3 mrems to the total body, and about 2 percent of the MPRI for bone.

Analyses of miscellaneous fresh produce purchased during the 1963 growing season from local farms and markets substantiated prior experience that only small quantities of radionuclides are present in locally grown produce under normal plant operating conditions.

The average concentration of I^{131} measured on samples of leafy vegetables collected from local farms and vegetable markets during the period of May through September was less than or approximately equivalent to the detection level of 0.05 pc/g. Considering a consumption rate of 100 g of leafy vegetables per day throughout the 5 month growing season, the average annual intake from local vegetables would be about 750 pc I^{131}. Such an intake implies an annual exposure of about 1 mrem to the thyroid of a "standard man".

Concentrations of I^{131} in Cattle Thyroids

The collection of thyroids from cattle slaughtered at Pasco was initiated in 1960 and then broadened in 1962 to include collection of thyroids of cattle slaughtered at Moses Lake, Toppenish, Walla Walla, and Wenatchee. Since the concentration of I^{131} in bovine thyroids is about 2 orders of magnitude higher than that in the pasture grass or in milk, it is advantageous to use thyroid measurements to follow probable trends in concentrations of I^{131} in milk and farm produce when the levels in milk and vegetables are too low for practical measurement. The sensitivity of cattle thyroids is evident from the significant increase in I^{131} concentrations observed for a short period in September following the unplanned release of I^{131} from one of the chemical separations facili-

[3] The Federal Radiation Council does not consider fallout from the testing of weapons to be from "normal peacetime operations" and thus subject to Radiation Protection Guides applicable to industry.

ties. The maximum concentration, however, was only 62 pc/g, which was considerably less than levels observed in late 1962 and early 1963 as a result of I^{131} from fallout.

Radioactive Particulates in the Atmosphere

Air sampling stations are maintained at several locations within the Hanford reservation and at several sites throughout the Pacific Northwest. Sample filters are changed weekly by cooperating agencies at Seattle, Spokane, Walla Walla, and Yakima in Washington; Meacham and Klamath Falls in Oregon; Boise and Lewiston in Idaho; and Great Falls, Montana. These filters are sent to Hanford where they are analyzed for total beta activity.

During the early part of 1963, the activity observed on air filters remained at nearly the level measured following USSR nuclear testing in the fall of 1962. Two peak activity periods occurred, one in February and one in May, indicating an influx of world-wide fallout. Analysis of the May activity, the highest since the fall of 1961, indicated the material was approximately 1 year old. In August a very rapid decline in concentrations occurred and by October the level was about 1 pc β/m^3.

Results of air filter samples are not used in estimating exposure but serve to illustrate the trends in atmospheric contamination. Sudden changes in concentrations are used to signal the need for shifted emphasis in other portions of the environmental monitoring program related to atmospheric contamination.

External Radiation

Measurements with ionization chambers stationed above the ground and submerged in the Columbia River were used to estimate the combined exposure from external sources in the vicinity of the Hanford project. Measurements over the ground indicated that the annual exposure for 1963 was about 170 mr, essentially the same as measured during 1962. Virtually all of this radiation originates from natural background and world-wide fallout from nuclear testing, and any additional contribution from Hanford sources is not readily discernible. Background measurements were relatively low during the first part of the year, and then increased during the latter half of the year.

Immersion dose measurements were obtained with pocket-type ionization chambers submerged 2 to 5 feet below the surface of the Columbia River. Exposure rates in the river are higher than those measured over land because of the presence of gamma emitters, especially Na^{24}, from reactor effluent. Near Richland and Pasco the average dose rates measured in the river during the months of April through October were about 2 and 1.5 mr per day, respectively. Further upsteam near the laboratories area the dose rate was 3 mr per day. A person swimming or boating in the river for 240 hours during the year would receive about 20 mr total body exposure in the vicinity of Richland and about 15 mr near Pasco.

At the river shoreline radiation measurements indicated the dose rate was about 0.25 mr/hour from radionuclides deposited with debris and in the mud and sand by the fluctuating water level. An ardent fisherman spending 6 hours per week, 8 months of the year, along the river bank in the vicinity of Richland would receive an annual whole body exposure of about 50 mr.

Radioactive Wastes Released to Ground

Liquid wastes from the Chemical Separations areas are routed to various facilities dependent upon their burden of radionuclides. High level wastes, normally containing concentrations greater than 100 $\mu c/cc$, are stored in concrete tanks lined with steel. Intermediate level wastes, ordinarily containing concentrations in the range of 5×10^{-5} $\mu c/cc$ to 100 $\mu c/cc$, are sent to underground "cribs" from which they percolate into the soil. Low level wastes, usually containing less than 5×10^{-5} $\mu c/cc$, are sent to depressions in the ground where surface ponds or "swamps" have been formed as a result of the continuous addition of relatively large volumes. The areas selected for liquid waste disposal have soil with good ion exchange capacity and depths of 150 to 350 feet to ground water.

One important objective in the management of wastes placed in the ground is the prevention of radiologically important radionuclides from reaching the ground water in quantities that could ultimately cause significant human exposure should they migrate to the Columbia River.

For this reason wells have been drilled in and around crib and tank storage areas to detect any leaks in the tanks and for measuring radionuclides that have reached the ground water. Virtually all of the radionuclides present in the ground water have been introduced with liquids sent to the cribs.

The quantity of radioactive materials sent to ground during 1963 (excluding tritium and the materials sent to the storage tanks) was about 36,000 curies. This did not significantly change the historical total which is estimated to be 2.6×10^6 curies. Because of radioactive decay, the current total in the ground is estimated as 2.6×10^5 curies. In order of abundance, the bulk of this material is Ru^{106}, Cs^{137}, and Sr^{90}.

The detectable beta contamination (not including tritium) in the ground water beneath the 200-W Area was less extensive in 1963 than in previous years. This resulted because of a reduction in the amount of contaminants discharged to ground, radioactive decay, and further dilution in the ground water.

A substantial amount of tritium has been sent to the ground with the intermediate level liquid wastes from the separations plant. In all probability some tritium and Ru^{106} originating at the chemical processing areas is now entering the Columbia River. However, the contribution of these nuclides is too small to be detectable in the river water and any exposure from them is negligible.

RADIATION EXPOSURE

The total radiation dose that is received from environmental sources differs substantially between individuals because their food and beverages come from various supplies, because the kinds and quantities consumed are subject to individual preference, because some people do more swimming, fishing, and boating than others, and because of other personal habits. These inherent variations between individuals require a somewhat subjective approach to the question of probable total exposure in relation to various limits. The Federal Radiation Council has provided two sets of guides against which exposures from environmental sources can be judged, *viz.* one for the individuals that receive the greatest exposure, the other for the average exposure received by an exposed population (taken as one-third that set for individuals). For the Hanford environs, possible exposures from the various sources described in the preceding sections have been combined in two ways to allow comparisons with both the individual and population guides. In one case a hypothetical, but plausible, individual has been assigned dietary and other habits that would result in what would seem to be the greatest rational exposure. As a second case, an exposure has been estimated for the "average" Tri-City resident. Several hundreds (perhaps a few thousands) of people receive more exposure than calculated for the "average" Tri-City resident but very few, (and quite possibly none) receive as much as that calculated for the "maximum" individual. Included in the intermediate group are the families that subsist largely on foodstuffs produced on farms irrigated with water taken from the Columbia River downstream from the plants.

The Maximum Individual

Attempts are being made to identify the individuals that actually receive the greatest exposure. Such individuals are undoubtedly persons that frequently eat fish caught locally in the Columbia River and produce grown on farms irrigated with Columbia River water. During the past 2 years, over 600 fishermen have been questioned by employees of the State of Washington Department of Game on their consumption of fish. The greatest consumption reported was about 200 meals per year, consisting dominantly of crappie, perch, bass, and catfish, caught near Burbank. On the basis of radiochemical analyses of such fish caught in this area, the intake of P^{32} for this individual during 1963 would have amounted to about 7 μc (about 45 percent of the NCRP limit). Whether the individual actually ate that much fish is not confirmed. Some other persons reporting unusually high consumption of local fish have been counted in the Whole Body Counter and contained far less Zn^{65} than predicted on the basis of their estimates of the quantities of fish eaten.

The reported consumption of 200 meals of local fish per year is used as a basis for calculating the maximum intake of radionuclides from this source. If this same individual is also assumed to consume each day over 2 qts. of water from the Pasco system, and about 1 qt.

of milk, ½ lb. of beef, and nearly ½ lb. of fresh leafy vegetables (in season), all produced on irrigated farms of the Rivierview District, the composite exposure from these sources amounts to about 15 percent of the appropriate limit for the GI tract, 50 percent of the limit for the bone, 1 percent of the limit for the thyroid, and 25 percent of the limit for the total body. The estimated exposure to the total body includes an increment of 50 mr received from the river bank while catching the fish. It also includes a contribution from ingested Sr^{90} that is unrealistically high (20 mrems) in relation to 1 year's intake, because it assumes an accumulation of Sr^{90} in the body that would only be gained over several decades.

The maximum thyroid dose is postulated to have occurred in a small child, rather than an adult, because of the relatively small mass (2 g versus 20 g for an adult) in which the ingested I^{131} accumulates.[4] On the basis of a daily intake of 1 liter of milk from a farm of the Riverview District, 0.8 liter of water from the Pasco system, and 50 g of fresh leafy vegetables, the intake of I^{131} for the year is estimated at about 6,700 pc, which would deliver a dose of about 115 mrems—about 7.5 percent of Radiation Protection Guide for individuals.

The Average Tri-City Resident

The vast majority of people who live in Richland, Pasco, and Kennewick obtain their food from local stores (rather than directly from farms) and do not eat fish caught from the Columbia River. The principal sources of radionuclides to these people are world-wide fallout (present to some extent in nearly all foodstuffs throughout the country) and drinking water pumped from the Columbia River.

The contribtuion from fallout is almost entirely associated with Sr^{90} and I^{131} and is assumed to be the same for all three cities. The Sr^{90} intake is estimated from dietary surveys made elsewhere in the United States and reported by the Federal Radiation Council (*6*) but adjusted on the basis of the Sr^{90} content of milk sold in local stores during 1963. The result is about 0.01 μc for the year, which would be about 15 percent of the FRC guide for a population exposed to Sr^{90} from a normal peacetime source.

The contribution from nuclides of Hanford origin in drinking water is substantially different for the three cities as discussed earlier. The dose to the GI tract was greater in Richland than in the cities further downriver because of a greater abundance of the short-lived nuclides. As shown previously in table 5, the exposure accrued during the last 4 months of 1963 is estimated at about 25 mrems—about 5% of the population limit. The value is expected to be proportionately higher in 1964 when exposure extends over a full 12-month period. The contribution to the GI dose from other sources was relatively insignificant. Conversely, the concentration of bone seekers, such as Sr^{90} and P^{32}, in the water was so low that drinking water did not significantly contribute to the bone dose.

The most appropriate "exposed population" to consider in relation to I^{131} intake and dose to the thyroid would appear to be small children of Pasco who drank water from the municipal system throughout the year (0.4 liters per day) as well as milk from the local stores (1 liter per day). Further, these same children were assumed to eat daily about 25 g of fresh vegetables obtained from local markets. The total intake of I^{131} for the year is estimated at about 2,000 pc or an average of about 5 pc per day. This is in the middle of the FRC Range I—the lowest range.

The estimated total body exposure from artificial radionuclides was about 15 mrems for the average Richland resident for 1963. Virtually all of this contribution is assigned to Sr^{90} from fallout and the method of calculation yields a value that is unrealistically high as mentioned in the case of the "Maximum Individual". The total dose does, however, include a small contribution (about 1 mrem) from nuclides of Hanford origin (principally Na^{24} and Zn^{65}) ingested with drinking water and (Zn^{65} only) beef and sea foods. This total body exposure may be compared with the FRC guide of 170 mrems for the average of suitable sample of an exposed population. Exposure from natural background sources in this region is estimated at about 150 mrems per year (excluded from the FRC guide).

[4] Editor's Note: Federal Radiation Council Guidance based on a projected dose for children approximately one year of age, assumes 30 percent retention of ingested iodine in a 2 gram thyroid, and ingestion of 1 liter of milk daily (*5*). Thus the maximum thyroid dose postulated in this report is highly conservative.

CONCLUSIONS

Comprehensive environmental surveillance of the Hanford environs during 1963 showed that the amounts of radioactive materials present were well within nationally accepted limits at all times and, thus, that the releases of radioactive wastes were adequately controlled.

The most significant source of exposure from the Hanford plants continued to be the P^{32} released to the Columbia River in the reactor effluent and subsequently concentrated by local fish. Individuals who ate such fish as a major part of their diet throughout the year and who also ate large quantities of produce grown on farms irrigated with Columbia River water could conceivably have taken in as much as 50% of the annual permissible amount of bone-seeking radionuclides.

One unusual release of I^{131} occurred from one of the separations plants in September. Extensive surveillance at the time showed that the temporary increase in the I^{131} content of milk and other foods did not substantially alter the annual radiation dose to thyroids of people living in the vicinity of the plant. More Sr^{90} from world-wide fallout was noted in 1963 than in 1963 and consequently the exposure from this source was slightly higher.

Previous coverage in *Radiological Health Data*

Period	Issue
1959 and first and second quarters 1960	*May 1961*
Third and fourth quarters 1960 and first and second quarters 1961	*February 1962*
Third and fourth quarter 1961	*October 1962*
Calendar year 1962	*January 1964*

2. Oak Ridge Area, January–June 1964

Union Carbide Nuclear Company, Oak Ridge, Tennessee

Oak Ridge Area is a complex made up of many installations, including K–25, X–10, and Y–12 areas, the Oak Ridge National Laboratory (ORNL), and the Oak Ridge Gaseous Diffusion Plant (ORGDP).

Radioactive waste materials arising from the operation of atomic energy installations in Oak Ridge Area are collected, treated, and disposed of according to their physical states. Solid wastes are buried in a Conasauga shale formation which has a marked ion exchange activity that enables it to fix radioactive materials. Liquid wastes which contain long-lived fission products are confined in storage tanks or are released to trenches located in the Conasauga shale formation. Low level liquid wastes are discharged, after preliminary treatment, to the surface streams. Air that may become contaminated by radioactive materials is exhausted to the atmosphere from several tall stacks after treatment by means of filters, scrubbers, and/or precipitators.

Air Monitoring

Atmospheric contamination by long-lived fission products and fallout occurring in the general environment of East Tennessee are monitored by two systems of monitoring stations. One system consists of seven stations which encircle the plant areas (figure 1) and provide data for evaluating the impact of all Oak Ridge operations on the immediate environment. A second system consists of seven stations encircling the Oak Ridge Area at distances of from 12 to 75 miles (figure 2). This system provides data to aid in evaluating local conditions and to assist in determining the spread or dispersal of contamination should a major incident occur. Sampling is carried out by passing air continuously through a filter paper. Average concentrations are presented in table 8.

TABLE 8.—LONG-LIVED GROSS BETA CONCENTRATIONS [1] IN AIR OAK RIDGE AREA

[Average concentrations in pc/m³]

Perimeter stations (see figure 1)	First half 1964	Remote stations (see figure 2)	Second half 1964
HP–31	1.3	HP–51	1.6
HP–32	1.5	HP–52	1.7
HP–33	1.1	HP–53	1.7
HP–34	1.2	HP–54	1.9
HP–35	1.4	HP–55	2.0
HP–36	1.4	HP–56	1.4
HP–37	1.3	HP–57	1.6
Average	1.3	Average	1.7

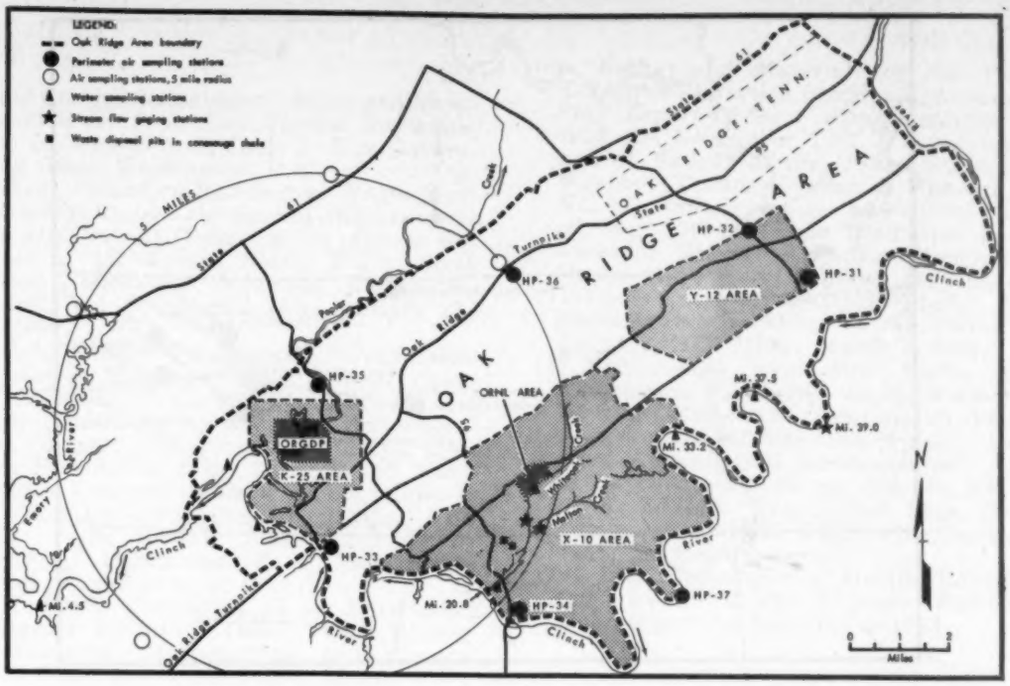

FIGURE 1.—OAK RIDGE AREA ENVIRONMENTAL SAMPLING LOCATIONS

Atmospheric contamination by uranium is determined by gross alpha measurements of continuous 8-hour air samples taken at five locations on a five-mile radius from the ORGDP (figure 1). The data are summarized in table 9.

TABLE 9.—LONG-LIVED ALPHA ACTIVITY IN AIR [1] FIVE MILES FROM ORGDP

[Average concentrations in pc/m³]

Direction from plant	First half 1964
North	0.3
East	0.45
Southwest	0.40

[1] Interpreted as uranium (natural).

Water Monitoring

Large volume, low level liquid wastes originating at ORNL are discharged, after some preliminary treatment, into the Tennessee River System by way of White Oak Creek and the Clinch River. Liquid wastes originating at the ORGDP and Y–12 Plant are discharged to Poplar Creek and thence to the Clinch River. The concentration of radioactivity leaving White Oak Creek is measured, and concentration values for the Clinch River are calculated on the basis of the dilution provided by the river.

Water samples are taken at a number of locations in the Clinch River, beginning at a point above the entry of wastes into the river and ending at Center's Ferry near Kingston, Tennessee. Stream gauging operations are carried on continuously by the U. S. Geological Survey to obtain dilution factors for calculating the probable concentrations of wastes in the river.

Samples are analyzed for the long-lived beta emitters, for uranium, and for the transuranic alpha emitters.

Analyses are made of the effluent for the long-lived radionuclides only, since cooling time and hold-up time in the waste effluent system is such that no short-lived radionuclides are present. The averages are given in tables 10 and 11.

Gamma Measurements

External gamma radiation levels are measured monthly at a number of locations in the Oak Ridge Area. Measurements are taken with a Geiger-Mueller tube at a distance of 3 feet above ground, and the results are shown in table 12 in terms of mr/hr.

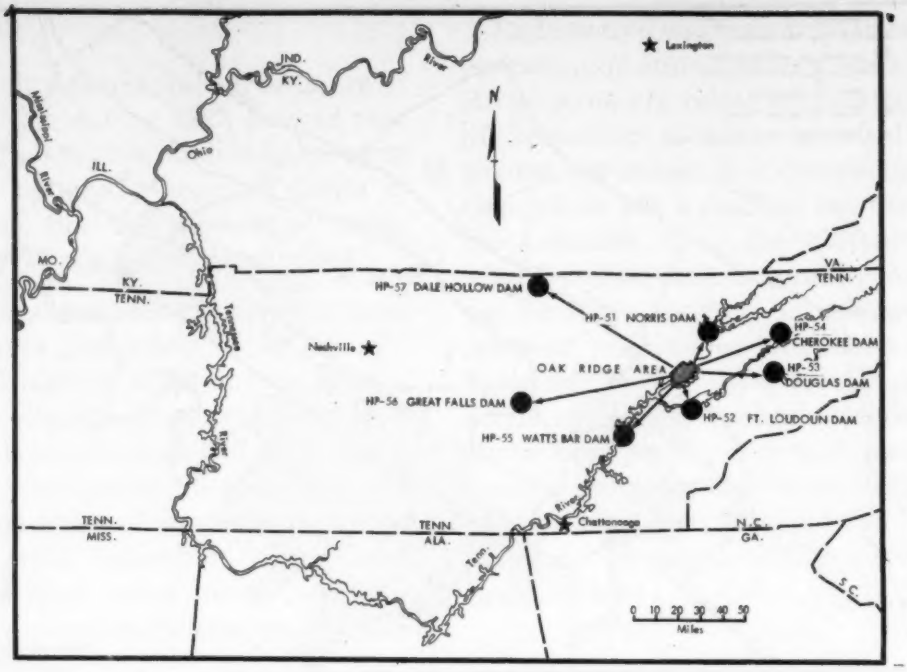

FIGURE 2.—REMOTE AIR MONITORING STATIONS; OAK RIDGE AREA

TABLE 10.—CONCENTRATIONS OF MAJOR RADIONUCLIDES IN THE CLINCH RIVER

[Average concentrations in pc/liter]

Radionuclide	First half 1964		
	Location on Clinch River [a]		
	Mi. 41.5 (Upstream)	Mi. 20.8 [b] (Outfall)	Mi. 4.5 (Downstream)
Sr^{90}	1.4	2.9	3.6
Ce^{144}	1.2	0.1	1.3
Cs^{137}	0.6	2.7	4.3
Ru^{106}	4.1	84	77
Co^{60}	—	6.0	6.5
Zr^{95}-Nb^{95}	0.1	<0.1	0.5
Gross beta	7.2	240	93

[a] The location on Clinch River is given in terms of the distance upstream from the Tennessee River. See figure 1.

[b] The concentrations at mi. 20.8 are not measured directly but the values are calculated on the basis of levels of waste released and the dilution afforded by the river.

TABLE 11.—URANIUM CONCENTRATIONS IN THE CLINCH RIVER, OAK RIDGE AREA

[Average concentrations in pc/liter]

Sampling location	First half 1964	
	No. of samples	Uranium concentration
Upstream from ORGDP	24	1
Downstream from ORGDP	24	1

TABLE 12.—EXTERNAL GAMMA RADIATION LEVELS, OAK RIDGE AREA

[Average dose rates in mr/hr]

Location	First half 1964
Solway Gate	0.015
Y-12 East Portal	0.012
Newcomb Road	0.014
Gallaher Gate	0.016
White Wing Gate	0.013
Average	0.014

Previous coverage in *Radiological Health Data:*

Period	Issue
1959 and first quarter 1960	*December 1960*
Second and third quarters 1960	*March 1961*
Fourth quarter 1960	*July 1961*
First and second quarters 1961	*January 1962*
Third and fourth quarters 1961	*September 1962*
1962	*September 1963*
1963	*July 1964*

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REPORTED NUCLEAR DETONATIONS, DECEMBER 1964

Four United States nuclear tests were announced by the Atomic Energy Commission during December 1964. The first, an underground test of low-intermediate yield (20–200 kilotons), took place at the Nevada Test Site on December 5. On December 16 two low-yield underground tests were conducted at the Site. (Low yield is defined as less than 20 kilotons of TNT.)

The December 18 test was another in the series of Plowshare experiments for peaceful uses of nuclear explosives. This 1/10 kiloton yield test was conducted at a depth of 90 feet.

These tests have been assigned the arbitrary *RHD* reference numbers 173 through 176 in order of their occurrence.